On-Site Grinding of Residential Construction Debris: The Indiana Grinder Pilot

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The information presented in this document does not constitute an endorsement of specific products or manufacturers; trade or manufacturers' names appear herein solely because they are considered essential to the information provided.

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EXECUTIVE SUMMARY

The objective of the pilot project documented in this report was to determine the feasibility of on-site grinding of clean wood, drywall, and cardboard waste from new residential construction as an alternative to conventional landfilling. The evaluation included the identification and assessment of the major technological, economic, and environmental factors associated with the grinding technique. The pilot project was established near Indianapolis, Indiana and involved several organizations, including residential builders and a waste management firm. Although it is not possible for a single case study to comprehensively address all of the issues involved in on-site grinding, key results are presented below.

Technological Feasibility

- *Grinder selection.* Identifying the grinder for the pilot project required significant amounts of time from several individuals, including home builders, Indiana Department of Environmental Management (IDEM) and the Indiana Department of Commerce. Very few manufacturers offer a piece of equipment capable of meeting requirements of mobility, particle size, customer-friendly operation, and cost.

- *Grinder description.* The machine selected is a top-loading, low-speed, horizontal-drive grinder manufactured by Concept Products Corporation of Paoli, PA under the model name “Shred-All”. The shredding mechanism of the Shred-All is a low-speed (28-80 RPM), six foot long auger-shaft with 35 replaceable teeth, which is powered by a 125 horsepower John Deere diesel engine. The entire assembly is mounted on a double axle trailer weighing approximately 8,000 pounds.

- *Grinder throughput.* The average throughput of the grinder was approximately 10 cubic yards per hour for wood and slightly higher (10.5 to 11 cubic yards/hour) for drywall and cardboard.

- *Volume reduction.* Wood volume was reduced approximately 50 percent, drywall approximately 60 percent.

- *Particle size.* Approximately 80 percent of the processed wood was less than 2-inches in size, with the remaining 20 percent ranging up to 6-inches. The gypsum wallboard was essentially processed into dust, and the paper facing was processed into 3-inch minus. The portion of “large” wood fragments, combined with the lack of a recycling outlet for the wood chips, was a key barrier to the custom builders incorporating the grinding technique into their job site practice.

- *Grinder down-time.* The accumulation of drywall dust was determined to be the primary cause of repeated overheating. Several actions were taken to address the

problem including mechanical repairs, installing a water system to eliminate dust, and more frequent cleaning of the filters and radiators. By the conclusion of the project the grinder was operating efficiently and dependably.

- *Safety.* There were no injuries reported over the course of the pilot and operators stated that the grinder was straightforward and safe to operate.

Economic Feasibility

- *Cost of the grinding service*. Based on the pilot project conditions, i.e., moderately high tipping fees, modest labor rates, and low transportation costs, the grinding service was cost-competitive with conventional landfilling. The cost of the grinding technique when servicing *production and custom builders* was estimated at $780/house; the cost of the grinding technique when servicing *production builders only* was estimated at $660/house; and the cost of conventional landfilling with roll-off trucks and dumpsters was estimated at $840/house. The savings is largely due to avoided disposal costs.

- *Operating & ownership costs.* The estimated annual machine cost of the grinder (based on 1,000 hours of operation) is $17.00 per hour (excluding labor costs). The cost for routine maintenance and fuel (per 1000 hours of operation) is estimated at $3,578.

- *Impact of builders' practice on economic feasibility.* This pilot included one production builder and five custom builders. The production builder in the pilot applied the processed material on nearby sites, successfully using the wood chips for erosion control and the drywall as a soil amendment. The custom builders, without soon-to-be-developed sites nearby, did not haul the processed material from the site and attempted to use the wood chips as landscape mulch or as a soil amendment. The custom builders' attempts were not successful because the large particle size of the wood chips were aesthetically unacceptable while the lawn reached maturity (the custom builders seeded their lawns), and because most homeowners were not interested in landscape mulch. The custom builders therefore did not have a cost-effective use for the processed material.

- *Impact of tipping fees on economic feasibility.* An economic sensitivity analysis indicates that in conditions of lower tipping fees the grinding service was competitive with conventional landfilling only when servicing production builders, i.e., with significantly less set-up/take-down and travel costs. In other words, the cost of conventional landfilling is largely determined by tipping fees, i.e., the cost of dumping at the landfill, whereas the cost of grinding services are not.

Environmental Feasibility

- *Soil testing*. The primary concern of the Indiana Department of Environmental Management was the carbon/nitrogen ratios (C/N) in the soil immediately after site application. Soil testing conducted by IDEM at the conclusion of the pilot found no significant difference in C/N ratios between soils having received the soil amendments and adjacent soils not having received the amendment. In addition, the soil testing conducted by IDEM at the conclusion of the pilot detected no elevated levels of heavy metals in the soil samples. These test results lead to the development of guidelines for site application (which are presented in Appendix D).

- *Policy/regulations on "treated" wood products*. After review of the pilot project conditions and their own policies and regulations IDEM supported the development of the application guidelines presented in Appendix D. These guidelines permit the application of processed engineered wood products such as plywood and OSB (oriented strand board), but do not permit the application of pressure-treated wood.

- *Components of the waste stream*. Wood, drywall and cardboard comprised approximately 70-75 percent of the total waste stream on the construction sites involved in the pilot project. This percentage is similar to the national average.

INTRODUCTION

Background

An estimated 136 million tons of building-related construction and demolition (C&D) debris were generated in 1996 in the United States.[1] It is estimated that residential construction, at the rate of roughly 4 tons per house, generated over 6.5 million tons (approximately 5 percent of this C&D total) in 1996. Detailed waste assessments have determined that approximately 75 percent of this waste stream consists of wood, drywall and cardboard, much of which is potentially recyclable or reusable, and another 10 percent is also potentially recyclable. Despite the fact that 85-90 percent of this waste stream is potentially recyclable or reusable, the most common management practice for this debris is landfilling at C&D landfills, municipal solid waste (MSW) landfills, and unpermitted sites.

In many regions of the United States the weak demand for many recyclable construction waste materials, combined with the high cost of transportation, results in few cost-competitive alternatives to conventional landfilling. With the recent design and development of specialized mechanical equipment, one promising alternative is grinding the wood, drywall, and cardboard scraps and reusing the processed material on-site as a soil amendment and for erosion control, and/or off-site as a feedstock for mulch and compost products. However, builders, haulers and material processors attempting such a practice have many questions about the technological, economic and environmental feasibility of grinding and reuse.

One of the important environmental feasibility questions was answered with the July, 1996 publication of *Scrap Construction Gypsum Utilization*, prepared by the United States Department of Agriculture-Agricultural Research Service. The report presents research demonstrating that the beneficial effects of pulverized gypsum wallboard waste are nearly identical to those of agricultural grade gypsum. Concurrently, new information on potentially viable grinding equipment was identified through state and regional recycling/solid waste expositions. The grinding and reuse technique also gained exposure through its profile in the NAHB Research Center's publication *Residential Construction Waste Management: A Builder's Field Guide*, released in January of 1997.

With some of the key environmental and technological feasibility questions addressed, questions regarding the economic feasibility of the grinding technique could now be addressed as well. Beginning in the summer of 1997, the Indiana Department of Environmental Management (IDEM), several home builders in Hancock County (the adjacent county to the east of Marion County/Indianapolis), and the NAHB Research Center (with support from the U.S. Environmental Protection Agency) began discussing the structure of a pilot project, and several

[1] Franklin Associates, *Characterization of Building-Related Construction and Demolition Debris in the United States*, June 1998.

grinders were demonstrated and evaluated[2]. The equipment for the pilot project was selected in January of 1998 and the IDEM Grant was approved in the spring of 1998. The six month pilot occurred from late April to October 31, 1998.

Objectives and Structure of the Report

The goal of the pilot project documented in this report was to determine the feasibility of the on-site grinding of the wood, drywall, and cardboard components of the new residential construction waste stream as an alternative to conventional landfilling. The feasibility evaluation included the identification and assessment of the major technological, economic, and environmental factors associated with the grinding technique. Specific project objectives were as follows:

- To identify a machine capable of grinding wood, drywall and cardboard to the requirements of project participants' needs, i.e., mobility, output particle size, etc.;

- To determine the costs of operating the equipment;

- To determine the economic feasibility of establishing a waste management business based on the grinding technique;

- To identify the environmental issues associated with the technique, and to establish guidelines for the on-site application of the processed material based on the identified environmental concerns; and

- To disseminate the results of the on-site grinding and reuse technique.

This report is structured around the major sections described below.

Project Description - The Indiana grinder pilot involved many participants including builders, an equipment operator, governmental agencies and trade associations.

Project Results - Information on the technological, economic, and environmental feasibility of the grinding technique form the body of this report.

Appendices - Detailed information on certain topics such as machine specifications, annual machine costs, the estimated costs of various waste management services, and educational fact sheets has been place in appendices to maintain the flow of the report.

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[2] Identifying the grinding equipment required input from several individuals. In addition, the manufacturers of suitable equipment were not easily identified. For a description of this task see the Technological Feasibility section included in the "Project Results".

PROJECT DESCRIPTION

Project participants

The project participants were as follows:

Project sponsor - The project was sponsored by the Indiana Department of Environmental Management (IDEM), and the United States Environmental Protection Agency.
Project management - Project accounting and administration were the responsibility of the Builders Association of Greater Indianapolis (BAGI).
Home builders - The project involved several home builders including Carrington Homes, Ivy Homes, George Sherman Builder, Dave Sego Builders, Spectrum Homes, Patriot and Ashford.
Equipment purchaser - The grinder used during the pilot project was purchased by a local equipment supplier who leased it to the project manager.
Equipment operator - The grinder was operated by Gibson Management Group during the pilot phase, who acted as a subcontractor to the project manager.
Project recorder - The responsibilities of tracking daily activities and completing log books were Richard Knight's, a local retired mechanical engineer.
Project consultant - Technical assistance, general support, and final report preparation was the responsibility of the National Association of Home Builders Research Center.

Builders' Waste Management Practice

Before the pilot project

Prior to the start of the pilot project many of the participating builders were using a clean-up service (operated by Gibson Management Group) to handle their construction debris. As is typical of clean-up services, Gibson Management Group eliminated the standard 30-yard roll-off service and instead provided jobsites with 10- and 20-yard wire bins. The builders' (and/or their subcontractors) were responsible for placing the unsorted waste material in the bins, and the clean-up service was responsible for removing the material from the site (this was done with manual labor and a 10-yard stake body truck). All of the material was hauled to nearby transfer stations and/or landfills. The fees for this service were based solely on volume, i.e., by the cubic yard.

During the pilot project

Five custom builders and one production builder agreed to participate in the pilot project. The same 10- and 20- yard wire bins were used during the pilot phase to contain the construction debris. Although the builders/subcontractors were similarly required to place the waste material in the bin, during the pilot phase a separate bin was placed for the grind-able material, i.e., wood, drywall, and cardboard. Upon request by the builder, the sites were serviced by Gibson Management Group who towed the grinder to the individual sites. The processed wood, drywall and cardboard were left on-site for use by the builder, and all other construction debris was hauled to nearby transfer stations and/or landfills. The fees for the grinding service were hourly, and the fees for hauling debris off-site were based on volume.

The primary use for the processed material was intended to be the construction site on which the debris was generated. Although other outlets would be pursued, the pilot intended to determine the feasibility of using the material on-site and thereby eliminate transportation.

PROJECT RESULTS

Technological Feasibility

Identifying/selecting the grinder

Identifying the grinder for the pilot project required significant amounts of time from several individuals, including home builders, IDEM and the Indiana Department of Commerce. Very few manufacturers offer a piece of equipment capable of serving the many participants' needs. The grinders were evaluated on the following criteria:

- *Mobility* - the machine would serve individual residential construction sites, and therefore should be small enough and easy enough to maneuver on typical building lots;
- *Particle size* - many of the builders initially intended to use the wood chips topically, e.g., as a mulch, and therefore required a small end-product;
- *Customer friendly-operation* – the machine would process material in the immediate vicinity of occupied homes, and therefore could not create excessive noise, dust, blowing paper, etc; and
- *Cost* – the total purchase cost or lease cost of the equipment was roughly targeted at less than $100,000.

Grinder description

The machine selected is a top-loading, low-speed, horizontal-drive grinder manufactured by Concept Products Corporation of Paoli, Pennsylvania under the name "Shred-All" (see Photo 1). The shredding mechanism of the Shred-All is a low-speed (28-80 RPM), six foot long, auger-shaft with 35 replaceable teeth, which is powered by a 125 horsepower John Deere diesel engine (see Photo 2). The dual-axle, grinder-trailer assembly measures 8'-0" long and 6'-0" wide and weighs approximately 8000 pounds, and can be pulled with one-ton pick-up truck.

Photo 1 – "Shred-All" Grinder

Photo 2 – Auger shaft

The bottom of the loading hopper is roughly 6 feet above ground, allowing the machine to be loaded manually. The optional hopper extension expands the capacity of the hopper to 2.5 cubic yards. The optional in-line conveyor is 9 feet long and equipped with an electric winch allowing the delivery of output to a variety of heights. For a complete listing of the machine's specifications see Appendix A.

Grinder performance

In general the grinder performed well and provided the opportunity to fully explore the other objectives of the pilot project, i.e., the economic and environmental feasibility. Although by the conclusion of the project the grinder was operating efficiently and dependably, operation during the six month pilot included various processing strategies as well as mechanical problems, which are all explained in the sections below.

- *Throughput* - The average throughput, i.e., output, of the machine was approximately 10 cubic yards/hour for wood and slightly higher (10.5 to 11 cubic yards/hour) for drywall and cardboard. Increasing the size of the output door opening from one to three inches increased the throughput roughly 10 percent (and increased the particle size - see below). In most cases the grinder was loaded manually by two workers – experimentation with mechanical loading (a skid-steer loader) did not increase the throughput. Throughput was not affected by the speed of the engine/auger.

- *Volume reduction* - Processing the material in the grinder reduced the volume of wood approximately 50 percent, and the drywall volume was reduced 60 percent. Due to the difficulty of measuring the volume of cardboard the reduction percentage was not observed.

- *Particle size* - Approximately 80 percent of the processed wood was less than 2-inches in size (see Photo 3). The gypsum in the drywall was essentially processed into dust, and the paper facing was processed into 3-inch or minus. Lowering the output doors to their lowest level did not reduced overall particle size, although it did modestly reduce the amount of wood chips larger than 2-inches from 20 to 15 percent. The portion of "large" wood fragments, combined with the lack of a recycling outlet, was a key barrier to the custom builders incorporating the grinding technique into their job site practice (this is discussed in the Environmental Feasibility section of this report).

Photo 3 – Sample of processed wood chips (wallet shown in foreground for scale)

- *Overheating problems* - During the first four months of the pilot the operating temperatures of the water and hydraulic oil repeatedly rose to levels which activated the grinder's automatic shut-down systems. The accumulation of drywall dust was determined to be the cause of the overheating and several actions were taken over the course of the six month pilot to address this. These actions are listed chronologically below. The grinder did not experience any major problems (overheating or otherwise) during the last two months of the pilot.

    1) installing a rubber sheet near the output doors;
    2) covering the radiator with a fine wire screen;
    3) remounting the air filter assembly completely outside the engine component;
    4) installing a hydraulic oil cooling system outside the engine compartment;
    5) installing a water/misting system (see Dust section below); and
    6) cleaning the filters and radiators more frequently.

- *Dust* - A water system designed to reduce the dust (primarily from drywall) generated from grinding was installed during the pilot. The water system included three misting heads located in the hopper/auger area, supply lines and an electric pump (see Photo 4). Although no on-board tank was included in the system, a fitting for connection to a residential hose bib was provided. The misting was only frequently required, and only one complaint was received about the dust during the six-month project (the complaint came from a homeowner living near a construction/grinding site and did not involve any health implications).

Photo 4 – Water/misting system

- *Loading* - Wood particles up to six-inches wide were fed into the grinder. Odd-shaped pieces of structural sheathing and long pieces of 2x material required careful loading to avoid jamming and/or flying debris. The hopper on the grinder could only be loaded from one side, and the in-line discharge conveyor did not swing from side to side, complicating maneuverability/access on site. Soft ground caused by wet weather also limited the maneuverability of the grinder. Operators noted that wet material did "gum-up" in the grinder but did not create any processing problems.

- *Conveyor discharge* - The slope of the conveyor was limited to approximately 45 degrees which created a bottleneck at the output doors (see Photo 1). The equipment operators speculated that decreasing the slope of the belt to less than 45 degrees, increasing the height of the cleats on the belt, or eliminating the conveyor all together may increase the throughput.
- *Fuel consumption* - The average fuel consumption of the grinder during the pilot project was approximately 2 gallons/hour of operation.

- *Safety* - The grinder operators reported no injuries and stated that the equipment was very safe to operate. The grinder operates at low-speeds, and the bottom of the loading hopper is approximately four feet above the auger and six feet above ground. The grinder is equipped with an emergency kill switch.

Grinder maintenance

Given that the grinder is a relatively new and innovative product with a limited performance record the maintenance required on the machine can only be estimated. Although mechanical problems were experienced during the pilot project all of these were relatively minor. Table B1 in Appendix B presents annual operating costs, and Table B1a presents the manufacturer's recommended maintenance schedule for consumable items, i.e., belts, fluids, filters, tires, teeth, and their approximate costs. The cost for routine maintenance and fuel to operate the grinder (per 1000 hours) is estimated at $3,578.

All of the repairs required during the pilot were covered by the manufacturer's one year full warranty and two year warranty on the engine. More information on the performance record of the grinder used in the pilot may be available from the manufacturer.

Economic Feasibility

As discussed in the Introduction and Project Description sections of this report, one of the primary objectives of the project was to determine the economic feasibility of the on-site grinding technique. To meet this objective, the following steps were taken:

1. Determine the local economic conditions in which the machines operated (based on information compiled during the pilot);
2. Estimate the costs of the machines required to operate an on-site grinding service (also based on information compiled during the pilot);
3. Estimate and compare the costs of various grinding and landfilling services (based on #1 and 2 above); and
4. Extend the economic analysis to consider the sensitivity of results to key variables such as tipping fees, labor rates, and transportation costs. These variables are the principal elements of the total waste management cost.

Local economic conditions

The local economic conditions in which the pilot project occurred included the following characteristics:

- *Tipping fees and tipping locations* - Tipping fees at the two solid waste facilities in Hancock County (the location of the grinder pilot) permitted to accept construction and demolition debris (both transfer stations) were approximately $10/cubic yard and $14/cubic yard. All of the debris generated during the pilot destined for the landfill went to these two transfer stations. The tipping fees at other area solid waste facilities ranged from $9-13/cubic yard[3]. The two transfer stations in Hancock County were located roughly 10 miles from the construction sites used during the pilot.

- *Landfill capacities* - Hancock County closed its only landfill in June of 1997 and now hauls its solid waste to, among other destinations, nearby Marion, Randolph, and Shelby Counties. Based on 1995 data, the capacities (in years) at the sanitary landfills in those counties are 10, 16, and 41, respectively. The majority of the solid waste collected at the two Hancock County transfer stations is hauled to a landfill in Randolph County approximately 70 miles to the east.

- *Available recycling outlets* - The primary use for the processed material was intended to be the construction site on which the debris was generated. Although other reuse and recycling outlets were pursued (building material reuse centers, landscaping yards, hog fuel, etc.), no such facilities were identified in the pilot project vicinity.

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[3] Based on a conversion of 350 pounds per cubic yard (or 5.7 cubic yards per ton) for mixed construction debris from residential jobsites, the $12.00/cubic yard tipping fee is equivalent to $68.40 per ton.

- *Predominant waste management method* - Most builders in the greater Indianapolis metropolitan area landfill their construction debris using a roll-off dumpster service. The cost for the roll-off service ranged from approximately $400 to $500 per dumpster.

Machine costs

Table 1 presents the estimated costs to own and operate the grinder used in the project, as well as the cost of the equipment which could be used to support the technique. For example, to support the grinding technique at the production level presented in Tables 1 and 2, the following equipment would likely be required: a dump body truck to tow the grinder and haul processed material; a stake body truck to haul other construction debris to the landfill; and a skid-steer loader for applying the processed material at the site. Important notes related to Table 1 are listed below.

- The costs are a function of annual use and therefore will vary depending upon the scenario in which the machines are used. The annual use, and the ownership and operation costs on which these estimates are based are itemized in Appendix B.
- The costs do not include a line item for labor. The labor costs, given that most of the machines can operate with one- and two-person crews, are considered in the individual scenarios presented in Appendix C.

Table 1 - Estimated Cost of Machines Required to Operate Grinding Service

Machine	Cost[1]	Annual Use
Grinder	$ 17.00/hour	1,000 hours
Dump Body (F350, 10-yards)	$ 0.90/mile	10,000 miles
Stake Body (GM Diesel, 10-yard capacity)	$ 0.60/mile	15,000 miles
Skid-steer loader	$ 12.10/hour	300 hours

1. The cost has been rounded to the nearest $10.

Extended economic analysis

Using the estimated costs presented in Table 1 the total cost of various grinding and landfilling services are projected and compared in Table 2 (the assumptions for these costs are presented in detail in Appendix C). It is important to note that Table 2 does not present costs as reported by pilot participants, but rather presents costs based on key information from the pilot, e.g., throughput, set-up/take-down time, travel time, etc.[4] In addition to presenting the pilot project conditions, Table 2 extends the economic analysis to consider the sensitivity of results to key variables such as labor rates, tipping fees, and transportation costs. It is also important to note that these represent costs to the *owner/operator of the equipment* (which could be the builder or a subcontractor).

[4] The structure of the pilot project, which included invoicing the project manager for hourly grinding services, did not produce waste management costs on a per house basis.

Table 2 - Cost Comparison of Services & Sensitivity Analysis

Service Type	Cost For Service ($/House)[1]			
	Pilot Project Conditions	With Lower Tipping Fees[2]	With Lower Labor Rates[3]	With Longer Travel Distances[4]
Grinding for production builders only	660	570	560	690
Grinding for custom & production builders	780	690	670	880
Landfilling with Clean-Up service	1,280	920	1,050	1,500
Landfilling with roll-off trucks and dumpsters	840	480	840	900

Assumptions:

1. The cost has been rounded to the nearest $10.
2. A tipping fee of $6/cubic yard (the pilot project conditions used $12/cubic yard).
3. A labor rate of $10/hour for debris-loading tasks, i.e., loading grinder and stake body truck (the pilot project conditions used $20/hour).
4. A travel distance of 20 miles from shop to sites, 20 miles from site to site (for custom sites) and 20 miles each way to landfill/transfer station (the pilot project conditions used 10 mile distances).

Analysis of the information provided in Table 2 suggests the following conclusions:

- *Overall economic feasibility*. The grinding service was more than cost-competitive with conventional landfilling given the pilot project conditions, i.e., moderately high tipping fees, modest labor rates, and low transportation costs. When serving production builders only, the grinding technique was $180 less per house than conventional landfilling, largely due to avoided disposal costs (see Table C5 in Appendix C for itemized costs). When serving production and custom builders the grinding technique was $60 less per house than conventional landfilling.

- *Impact of low tipping fees*. In conditions of lower tipping fees the grinding service would be competitive with conventional landfilling only when servicing production builders, i.e., with significantly less set-up/take-down and travel costs. In other words, conventional landfilling costs are largely determined by tipping fees, whereas grinding service costs are not (see Table C6 in Appendix C for itemized costs).

- *Impact of low labor rates*. A large percentage of the grinding service labor can be done by minimally-skilled workers, thereby reducing the cost of the service. Conventional landfilling with roll-off trucks and dumpsters requires a worker capable of driving and operating heavy equipment (see Table C7 in Appendix C for itemized costs).

- *Impact of longer travel distances*. For nearly all types of waste management service, increased travel has a larger impact on the number of sites which can be served than on the total cost of service (per house). Table 2 illustrates that increased travel time does increase the total cost per house for all service types, ranging from 5-15 percent. However, Table C8 in Appendix C illustrates that increased travel time decreases the maximum number of sites that can be served for all service types, some by as much as 38 percent. The maximum number of sites served with conventional roll-off trucks decreased 33 percent, while grinding for production builders dropped only 5 percent. This is due to the relatively small portion of the grinding service that is spent traveling, when compared to conventional roll-off trucks and dumpsters.

It should be noted that in some cases drywall contractors haul their own waste off the site and include the cost of this service in their total price for the house. Grinding the drywall and eliminating this added cost (approximately $50-100 per house) will further improve the economic feasibility of the grinding strategy. This cost is not included in the extended economic analysis.

Environmental Feasibility

There are of course many end-uses for processed wood and drywall in addition to land application, including recycling the wood chips for other wood and paper products and burning the wood chips as fuel. While the feasibility of the grinding technique in other areas of the country may in fact depend on other options, this report focuses on the environmental issues related to the end-uses pursued in this pilot project, i.e., using the processed material on a construction site.[5]

Types of land application

The types of land application considered in this pilot project and a brief description of each are listed below.

- *Landscape mulch*. Landscape mulch is used as a ground cover material to control weeds, prevent moisture loss in soil, and for aesthetic purposes. Wood chips can be stockpiled and used after construction to mulch landscape beds, shrubs, and islands around trees. In these applications, nitrogen can be added (20-30 pounds per acre) to aid decomposition. A concern with using construction scraps in this application is that the scraps may be too blonde in color. Furthermore, the adhesives in engineered wood products such as plywood and OSB significantly impairs the ability to color the wood scraps effectively, resulting in many cases in an aesthetically unacceptable product.

- *Road stabilization.* Wood chips provide strength and cohesion to the driving surface, and promote the drainage of water away from the driving surface. The primary characteristic required is that wood waste be either chips or slivers with a minimum of fines. The presence of too many fines decreases strength or adhesion, and inhibits water drainage.

- *Erosion control.* Wood chips can be used to stabilize soil while development is under way and can provide excellent erosion control on non-active sites as well. The use of wood waste for erosion control is limited to applications where bio-degradability is desirable. Examples include: spread on road shoulders, or other areas where heavy equipment is used; temporary low-flow drainage swales; used in months too hot, dry, or cold to establish vegetation; in areas where vegetation is not wanted; and in areas of bare soil needing protection.

- *Protecting tree roots*. One pass by one vehicle can compact the soil by 75 percent, crushing shallow roots and preventing water infiltration. Tree roots can be protected from damage and soil compaction by mulching over the root zone. Spreading a 10 to 12 inch layer of wood chips over the root zone will lessen the impact of heavy equipment.

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[5] For more information on reuse and recycling options see two publications offered by the NAHB Research Center - *Residential Construction Waste Management: A Builder's Field Guide*, and *Residential Construction Waste Management: A Coordinator's Guide*.

Issues with land application

Many states require that the applicator of processed material provide evidence that the proposed practice will benefit the land affected, while some states require proof of only a benign affect. The regulations permitting land applications vary from state to state, and therefore individuals considering land-application should contact their local Department of Environmental Protection.

The key issues affecting the land-application technique used in this project, and the IDEM position on these issues (where applicable) are listed below.

- *Carbon/nitrogen ratios in the soil*. The wood waste at new residential construction sites consists primarily of cut-off scrap generated during the framing stages. When the processed wood material is applied to the soil its elevated carbon/nitrogen ratio can adversely affect plant growth. This ratio will return to lower levels as the wood begins to decompose, but the rate at which the lower levels return are largely determined by the size of the wood particles (which in the case of the pilot included particle size larger than 2-inches). Soil testing conducted by IDEM at the conclusion of the pilot found no significant difference in C/N ratios between soils having received the soil amendments and adjacent soils not having received the amendment. These test results lead to the development of guidelines for site application (which are presented in Appendix D).

- *Formaldehyde-based adhesives in engineered wood products*. Engineered wood products such as plywood and oriented strand board are manufactured with adhesives, the affects of which on plant growth are uncertain. The soil testing conducted by IDEM at the conclusion of the pilot detected no elevated levels of heavy metals in the soil samples. In addition, IDEM also reviewed results from soil testing by the Orange Regional Landfill (Orange County, North Carolina) showing no measurable heavy metals or formaldehyde detected in wood waste piles consisting of C&D wood waste. [6]

- *Policy/regulations on "treated" wood products*. "Clean" wood waste is defined, in many cases, to include natural wood that has not been treated with chemicals or any potential contaminants. It includes wood residue harvested from commercial logging, forest management, site development and "clean" mill residues such as untreated pallets, dimensional lumber, some construction wood, and demolition wood that contains no physical or chemical additives. "Treated" wood waste is defined, in many cases, to include surface-coated wood (paints, stains, laminates, etc.), engineered-sheet products (plywood, OSB, etc.) and pressure-treated wood. After review of the pilot project conditions and their own policies and regulations IDEM supported the development of the application guidelines presented in Appendix D. These guidelines permit the application of processed engineered wood products such as plywood and OSB (oriented strand board), but do not permit the application of pressure-treated wood.

[6] Some individuals in the engineered wood industry believe these materials would make effective mulch since urea formaldehyde glues used in the materials could act as a source of slow-release nitrogen fertilizer. However, this has not been proven.

- *Other constituents used in wallboard manufacturing*. IDEM reviewed documents prepared by the US Department of Agriculture's Agricultural Research Service, indicating that the beneficial affects of pulverized gypsum wallboard waste are nearly identical to those of agricultural grade gypsum.

- *Local soil conditions*. The predominant soil classifications on the construction sites in the pilot project were "nearly level, poorly drained, loamy soils in glacial till", and "sloping well-drained and nearly level poorly drained, loamy and silty soils in glacial till".

- *One-time application*. When considering the utilization of processed wood and drywall as a soil amendment around construction sites, IDEM recognized that this was a one time application of the material and that the soils to which the material is applied will most probably be subsoil materials.

Builders' practice during the pilot

As explained earlier in the report, five custom builders and one production builder agreed to participate in the pilot project. The grinder operator serviced sites and left the processed wood, drywall and cardboard on-site for reuse by the builder. Approximately 20-25 percent of the processed wood was larger than 2-inches in size.

The production builder in the pilot applied the processed material on nearby, soon-to-be-developed sites, successfully using the wood chips for erosion control (see Photo 5) and the drywall as a soil amendment. The custom builders, without soon-to-be-developed sites nearby, did not haul the processed material from the site and attempted to use the wood chips as landscape mulch or as a soil amendment. These attempts were not successful because the large particle size of the wood chips were aesthetically unacceptable while the lawn reached maturity, and because most homeowners were not interested in landscape mulch. Some of the custom builders considered a second phase grinder to process the large chunks but this idea was not pursued, and eventually all of the custom builders withdrew from the pilot project. In sum, the grinding technique proved to be more feasible for the production builder than the custom builders for the following reasons:

- *Lawn planting.* Because the custom builders seed their lawns instead of planting sod the larger wood chips remain visible after the final grade. A production builder who plants sod-lawns will not have this problem (see Photos 6 and 7). Very few homeowners will request the processed wood piles be left on site for use as mulch (none requested this during the pilot).

- *Construction sequence*. The wood chips are generated after the foundation work and backfill is completed, and it is during this grading activity that the wood chips can be used effectively for erosion control. However, only production builders who have soon-to-be-developed lots nearby (where the processed material can be deposited) can cost-effectively employ this strategy.

- *Available equipment*. The task of applying the processed material on site is more burdensome for the custom home builders because they do not typically have the equipment or the staff for this task. A production builder typically has the required equipment, i.e., a skid-steer loader, readily available for this task.

- *Amount of "tillable" land*. The proper application of processed wood and gypsum wallboard requires a reasonable amount of tillable land (this application rate is described in detail in Appendix D). In many instances custom homes include one or more of the characteristics listed below, resulting in application rates which exceed the guidelines outlined in Appendix D.

    1) the homes are large and generate higher than average amounts of wood and drywall waste;
    2) the sites are smaller than average; and
    3) the sites contain large amounts of heavily wooded or otherwise "untillable" area.

Photo 5 – Site with processed material used for erosion control

Guidelines for site application

The NAHB Research Center prepared guidelines for the application of the material, which later received approval from IDEM. The project participants agreed that it was important to develop an educational fact sheet for the home buyers as well. Both the guidelines for the land application and the fact sheet for home buyers are presented in Appendix D.

Photo 6 – Site with processed material after final grading

Photo 7 – Site with processed material after sod-lawn

APPENDICES

A – Grinder Specifications

B – Estimate of Annual Machine Costs

C – Estimated Cost of Grinding and Landfilling Services

D – Educational Fact Sheets (Home builders, home buyers)

APPENDIX A - GRINDER SPECIFICATIONS

Appendix A

Shred-All Specifications[1]

Trailer	Size	7'-11" length, 6'-2" wide
	Axles	2
	Brakes	surge hydraulic or electric - both axles
	Lights	complete light package
	Ball size	2-5/16"; optional pintle hook
Hopper	Capacity (with optional extension)	2.5 cubic yards
	Accessibility	4 pin hopper door
	Size (standard)	8'-5" length, 3-4" width, 4' depth
	Size (extension)	11'-5" length, 3'-9" width, 4' depth
Auger	Speed	80 hp/100 hp - 18 to 65 RPM 115 hp/125 hp - 28 to 80 RPM
	Length	6' with 35 replaceable teeth
	Anvil bar	3 sections (replaceable)
	Trough	liner 1 section (replaceable)
Engine-Diesel	80 hp or 100 hp	7750 lbs. (shipping weight)
	115 hp or 125 hp	8000 lbs. (shipping weight) (additional weight with extension hopper, fully fueled, and conveyor 1,000 lbs.)
	Protection	high-water & high oil temp shutdown low oil shutdown
Hydrostatic Transmission/ Hydraulic Motor	Computer control features	load sensing timing control speed regulator overload protection automatic reverse
OPTIONS		
Hydraulic Conveyor	Size	9'-1/2" length
	Belt	16" wide with 2-1/2" cleats
	Weight	500 lbs.
	Winch	electric

1. The listed specifications were provided by Concept Products Corporation. For more information contact:

   Concept Products Corporation
   Paoli Corporate Center, Suite 110
   16 Industrial Blvd., Paoli, PA 19301
   Telephone (610) 722-0830
   Fax (610) 647-7210

APPENDIX B - ESTIMATE OF ANNUAL MACHINE COSTS

Appendix B

Estimate of Annual Machine Costs

B1 - Grinder
    B1a - Grinder Maintenance
B2 - Dump Body
B3 - Stake Body
B4 - Skid-Steer Loader
B5 - Roll-Off Truck
B6 - Roll-Off Dumpsters

B1 - ESTIMATE OF ANNUAL MACHINE COST
Grinder

Machine: Shred-All (grinder)
Conditions: purchase of new equipment

		Amount
1.	Purchase Cost……	$ 84,000[1]
2.	Salvage value……	$ 10,000
3.	Cost to be recovered ……	$ 74,000
4.	Estimated useful years of life……	8
5.	**Estimated annual use** (20 hrs/week x 50 weeks)[1] ……	1,000 hrs

Annual Ownership Costs:

6.	Annuity factor for cost recovery and interest[2]…… (interest rate = 6%)	0.1610
7.	Annual cost recovery and interest charge (7a plus 7b)……	$ 12,514
a.	line 3 x line 6…… $ 11,914	
b.	line 2 x interest rate 6%……$ 600	
8.	Insurance and taxes……	$ 800
9.	Other (license, shelter, etc.)……	$ 100
10.	Annual Ownership Cost (total lines 7 thru 9) ……	$ 13,414
11.	**Annual Ownership Cost per Unit (line 10/line5)** ……	$ 13.41/hr

Annual Operating Costs:

12.	Fuel (2 gal/hr. x 1,000 hrs. x $1.00/gal.) ……	$ 2,000
13.	Oil, grease, filters (see Table B1a - Maintenance schedule) ……	$ 970
14.	Repairs (teeth, tires) (see Table B1a - Maintenance schedule) ……	$ 608
15.	Other ……	0
16.	Annual Operating Cost (total lines 12 thru 15)……	$ 3,578.00
17.	**Annual Operating Cost per Unit (line 16/line 5)**……	$ 3.58/hr

Total Annual Costs:

18.	Total Annual Machine Cost (line 10 plus line 16)……	$ 16,992.00
19.	Total Cost per Unit (line 18/line 5)……	$ 16.99/hr

Notes/Assumptions:
1. Purchase cost as reported by pilot participants. Purchase cost reported by manufacturer is $62,000.
2. Derived from annuity table (not included) based on interest rate and useful life.

B1a - Grinder Maintenance Schedule

Item	**Service Frequency (Hours)**	**Cost per Service (Dollars)**	**Cost per 1000 hours of operation (Dollars)**
Engine oil and filter	100	30	300
Gear box oil	500	75	150
Hydraulic filter	100	20	200
Hydraulic oil	500	160	320
Teeth	1000 2000	272 272	272 136
Tires	As required		100 (est.)
Misc. (pumps, switches, etc.)	As required		100 (est.)
Total			**1,578**

B2 - ESTIMATE OF ANNUAL MACHINE COST
Dump Body

Machine: Dump Body (F350)
Conditions: purchase of new truck

			Amount
1.	Purchase Cost…………………………………………………………	$	40,000
2.	Salvage value…………………………………………………………	$	5,000
3.	Cost to be recovered ……………………………………………………	$	35,000
4.	Estimated useful years of life………………………………………..		8
5.	**Estimated annual use** (200 miles/week x 50 weeks)..………....….		10,000 miles

Annual Ownership Costs:

6.	Annuity factor for cost recovery and interest[1] ………………………. (interest rate = 6%)		0.1610
7.	Annual cost recovery and interest charge (7a plus 7b)………………..	$	5,935
	a. line 3 x line 6………………. $ 5,635		
	b. line 2 x interest rate %…….. $ 300		
8.	Insurance and taxes………………………………………………….	$	2,000
9.	Other (license, shelter, etc.)………………………………………….	$	100
10.	Annual Ownership Cost (total lines 7 thru 9) ……………………….	$	8,035
11.	**Annual Ownership Cost per Unit (line 10/line5)** ……………………	$	0.80/mile

Annual Operating Costs:

12.	Fuel (10 MPG x 10,000 miles x $1.05/gal.)…………………………..	$	1,050.00
13.	Oil, grease, filters (15% of fuel cost) …………………………………	$	157.50
14.	Repairs (4% of fuel cost) ………………………………………………	$	42.00
15.	Other ……………………………………………………………………	$	0
16.	Annual Operating Cost (total lines 12 thru 15)……………………..….	$	1,249.50
17.	**Annual Operating Cost per Unit (line 16/line 5)**……………………	$	0.12/mile

Total Annual Costs:

18.	Total Annual Machine Cost (line 10 plus line 16)……………………..	$	9,284.50
19.	Total Cost per Unit (line 18/line 5)…………………………………….	$	0.92/mile

Notes/Assumptions:
1. Derived from annuity table (not included) based on interest rate and useful life.

B3 - ESTIMATE OF ANNUAL MACHINE COST
Stake Body

Machine: 12-foot stake body truck (GM Diesel)
Conditions: purchase of new truck

			Amount
1.	Purchase Cost……………………………………………………………	$	30,000
2.	Salvage value…………………………………………………………	$	5,000
3.	Cost to be recovered …………………………………………………	$	25,000
4.	Estimated useful years of life……………………………………..…..		8
5.	**Estimated annual use** (300 miles/week x 50 weeks).. ………………		15,000 miles

Annual Ownership Costs:

6.	Annuity factor for cost recovery and interest[1] ………………………. (interest rate = 6%)	$	0.1610
7.	Annual cost recovery and interest charge (7a plus 7b)………………..	$	4,325
	a. line 3 x line 6………………. $ 4,025		
	b. line 2 x interest rate %…….. $ 300		
8.	Insurance and taxes………………………………………………….	$	2,000
9.	Other (license, shelter, etc.)………………………………………….	$	100
10.	Annual Ownership Cost (total lines 7 thru 9) …………………………….	$	6,425
11.	**Annual Ownership Cost per Unit (line 10/line5)** ……………………	$	0.43/mile

Annual Operating Costs:

12.	Fuel (10 MPG x 15,000 miles x 1.05/gal.) …………………………..	$	1,575.00
13.	Oil, grease, filters (15% of fuel costs) ..………………………………	$	236.25
14.	Repairs (4% of fuel costs) ……………………………………………	$	63.00
15.	Other ………………………………… ……………………………	$	0
16.	Annual Operating Cost (total lines 12 thru 15)……………………..…	$	1,874.25
17.	**Annual Operating Cost per Unit (line 16/line 5)**……………………	$	0.12/mile

Total Annual Costs:

18.	Total Annual Machine Cost (line 10 plus line 16)……………………..	$	8,299.25
19.	Total Cost per Unit (line 18/line 5)……………………………………	$	0.55/mile

Notes/Assumptions:
1. Derived from annuity table (not included) based on interest rate and useful life.

B4 - ESTIMATE OF ANNUAL MACHINE COST
Skid-Steer Loader

Machine: Skid-Steer Loader (Bobcat)
Conditions: purchase of new equipment

			Amount
1.	Purchase Cost…………………………………………………………	$	18,000
2.	Salvage value…………………………………………………………	$	5,000
3.	Cost to be recovered …………………………………………………	$	13,000
4.	Estimated useful years of life………………………………………..		8
5.	**Estimated annual use** (6 hrs/week x 50 weeks) …………………..		300 hours

Annual Ownership Costs:

6.	Annuity factor for cost recovery and interest[1] ………………………. (interest rate = 6%)		0.1610
7.	Annual cost recovery and interest charge (7a plus 7b)………………..	$	2,393
	a. line 3 x line 6………………. $ 2,093		
	b. line 2 x interest rate 6%….. $ 300		
8.	Insurance and taxes………………………………………………….	$	300
9.	Other (license, shelter, etc.)………………………………………….	$	50
10.	Annual Ownership Cost (total lines 7 thru 9) ………………………….	$	2,743
11.	**Annual Ownership Cost per Unit (line 10/line5)** ……………………	$	9.14/hr

Annual Operating Costs:

12.	Fuel (1 gal/hr. x 300 hrs. x $1/gal.)………………………………..	$	300
13.	Oil, grease, filters……………………………………………………	$	300
14.	Repairs………………………………………………………………	$	300
15.	Other ………………………………………………………………	$	0
16.	Annual Operating Cost (total lines 12 thru 15)……………………..…	$	900
17.	**Annual Operating Cost per Unit (line 16/line 5)**……………………	$	3.00/hr

Total Annual Costs:

18.	Total Annual Machine Cost (line 10 plus line 16)……………………..	$	3,643
19.	Total Cost per Unit (line 18/line 5)…………………………………….	$	12.14/hr

Notes/Assumptions:
1. Derived from annuity table (not included) based on interest rate and useful life.

B5 - ESTIMATE OF ANNUAL MACHINE COST
Roll-Off Truck

Machine: Mack roll-off truck, 10-wheeler, with hoist
Conditions: purchase of new truck

		Amount
1.	Purchase Cost…………………………………………………………	$ 95,000
2.	Salvage value………………………………………………………	$ 15,000
3.	Cost to be recovered ………………………………………………	$ 80,000
4.	Estimated useful years of life………………………………………	8
5.	**Estimated annual use** (650 miles/week x 50 weeks) ….…………..	32,500 miles

Annual Ownership Costs:

6.	Annuity factor for cost recovery and interest[1] ……………………… (interest rate = 6%)	0.1610
7.	Annual cost recovery and interest charge (7a plus 7b)…………. …..	$ 13,780
	a. line 3 x line 6………………. $ 12,880	
	b. line 2 x interest rate 6%….. $ 900	
8.	Insurance and taxes………………………………………………..…	$ 8,000
9.	Other (license, shelter, etc.)…………………………………….……	$ 700
10.	Annual Ownership Cost (total lines 7 thru 9)…….…………………...	$ 22,480
11.	**Annual Ownership Cost per Unit (line 10/line5)** …………………	$ 0.69/mile

Annual Operating Costs:

12.	Fuel (5 MPG x 32,500 miles x $1.00/gal.)…………………………..	$ 6,500
13.	Oil, grease, filters (15% of fuel costs)……………………………….	$ 975
14.	Repairs (4% of fuel costs)…………………………….……………..	$ 260
15.	Other (tires) ……………….……………………………………………	$ 4,000
16.	Annual Operating Cost (total lines 12 thru 15)……………………..…	$ 11,735
17.	**Annual Operating Cost per Unit (line 16/line 5)**…………………..	$ 0.36/mile

Total Annual Costs:

18.	Total Annual Machine Cost (line 10 plus line 16)……………………	$ 34,215
19.	Total Cost per Unit (line 18/line 5)………………………………..	$ 1.05/mile

Notes/Assumptions:
1. Derived from annuity table (not included) based on interest rate and useful life.

B6 - ESTIMATE OF ANNUAL EQUIPMENT COST
ROLL-OFF DUMPSTERS

Equipment: Fifty, 30-yard roll-off dumpsters
Conditions: Purchase of new equipment

		Amount
1.	Purchase Cost (50 dumpsters @ $2,500 each)…………………...$	125,000
2.	Salvage value……………………………………………………..$	5,000
3.	Cost to be recovered ……………………………………………..$	120,000
4.	Estimated useful years of life……………………………………..	10
5.	**Estimated annual use** (50 x 40 hrs/wk x 50 wks/year)…………	100,000 hrs

Annual Ownership Costs:

6.	Annuity factor for cost recovery and interest[1] …………………… (interest rate = 6%)	0.1359
7.	Annual cost recovery and interest charge (7a plus 7b)……………$	16,608
a.	line 3 x line 6………………. $ 16,308	
b.	line 2 x interest rate 6%…… $ 300	
8.	Insurance and taxes……………………………………………..$	0
9.	Other (license, shelter, etc.)……………………………………..$	0
10.	Annual Ownership Cost (total lines 7 thru 9) ……….…………..$	16,608
11.	**Annual Ownership Cost per Unit (line 10/line 5)** ………………$	0.17hr

Annual Operating Costs:

12.	Fuel (gal/hr. x hrs. x price/gal.)……………………………$	0
13.	Oil, grease, filters………………………………………………..$	0
14.	Repairs……………………………………………………………..$	0
15.	Labor ………………………………………………………………$	0
16.	Annual Operating Cost (total lines 12 thru 15)………………………$	0
17.	**Annual Operating Cost per Unit (line 16/line 5)**…………………$	0

Total Annual Costs:

18.	Total Annual Machine Cost (line 10 plus line 16)…………………..$	16,608
19.	Total Cost per Unit (line 18/line 5)…………………………………$	0.17/hr

Notes/Assumptions:
1. Derived from annuity table (not included) based on interest rate and useful life.

APPENDIX C - ESTIMATED COST OF GRINDING AND LANDFILLING SERVICES

Appendix C

Estimated Cost of Grinding and Landfilling Services

C1 - Grinding & Landfilling: Serving Production Builders Only
C2 - Grinding & Landfilling: Serving Custom and Production Builders
C3 - Conventional Landfilling: Serviced by Clean-Up Service
C4 - Conventional Landfilling: Serviced by Roll-off truck and dumpsters
C5 - Cost Comparison of Services: With Pilot Project Conditions
C6 - Cost Comparison of Services: With Lower Tipping Fees
C7 - Cost Comparison of Services: With Lower Labor Rates
C8 - Cost Comparison of Services: With Longer Travel Distances

C1 - ESTIMATED COST OF GRINDING AND LANDFILLING

Serving production builders only[1]

Service			**Cost ($)**		
Task	**Machine/Labor**	**Units (per week)**	**Unit Cost**[10]	**Weekly**	**Ann**
Grinding (crew of 2)	Grinder	30 hours[2]	$12.52/hour	375.60	
	Dump body (F350)	135 miles[3]	$1.31/mile	176.85	
	Skid-steer loader	6.7 hours[4]	$11.19/hour	74.97	
	Labor		all @ $20/hour		
	Grinder operating	60 hours		1,200.00	
	Set-up/take-down	6.7 hours[5]		134.00	
	Travel time	9.0 hours[6]		180.00	
	Skid-steer operating	6.7 hours[4]		133.33	
Landfilling (crew of 1)	Stake body truck	315 miles[7]	$0.53/mile	166.95	
	Labor		all @ $20/hour		
	Loading debris	28.6 hours[8]		572.00	
	Travel	10.5 hours[9]		210.00	
	Tip fees	100 cubic yards[8]	$12/cubic yard	1,200.00	
Total				**4,423.70**	**22**
Maximum Number of Houses Served (per year) ……… 333[4]					
Cost for service (per house) ………………………….. $664.22					

Assumptions

1. All homes serviced are within the same development; all are 2000 square foot homes generating 60 cubic yards of construction debris (of which 45 cubic yards are grind-able, 15 are hauled to landfill); each house is serviced three times during construction; and 100% operating efficiency.
2. Twenty site visits per week; grinding 15 cubic yards per visit; and 10 cubic yards per hour [(20 visits/wk x 15 cy/visit) / 10 cy/hour = 30 hours/wk].
3. A weekly route of: travel to and from storage shop (10 trips @ 10 miles each); travel from site to site (15 miles); and travel to drop-off processed material (20 miles) [(10 x 10) + 15 + 20 = 135 miles].
4. One hour per house to spread the processed material on site; twenty site visits per week; 50 weeks per year; and three visits per house.
   [(20 visits/wk x 50 wks/yr)/ 3 visits/house = 333 houses/yr; and [(333houses/yr x 1 hr/house)/ 50 wks/yr = 6.7 hrs/wk].
5. Five daily set-up and five daily take-downs @ 20 minutes each; and two workers [(5 + 5) x 0.33hrs/wk x 2 workers = 6.7 hrs/wk].
6. 135 miles traveled @ 30 miles per hour; and two workers [(135 miles x 2 workers)/ 30 miles/hr = 9 hours].
7. A weekly route consisting of: travel to and from storage shop (10 trips @ 10 miles each); travel from site to site (15 miles); and travel from sites to landfill/transfer station (10 trips @ 20 miles each) [(10 x 10) + 15 + (10 x 20) = 315 miles].
8. 100 cubic yards per week (20 visits @ 5 cubic yards each); and debris loaded onto truck @ 3.5 cubic yards/hour [(100 cy/wk)/ (3.5 cy/hr) = 28.6 hrs/wk].
9. 315 miles traveled @ 30 miles per hour [(315 miles)/ (30 miles/hr) = 10.5 hours].
10. Unit costs are based on estimates presented in Appendix B, adjusted for annual use.

C2 - Estimated Cost of Grinding and Landfilling

Serving custom and production builders[1]

Service			**Cost ($)**		
Task	**Machine/Labor**	**Units (per week)**	**Unit Cost**[10]	**Weekly**	**Annu**
Grinding (crew of 2)	Grinder	22.5 hours[2]	$15.50/hour	348.75	
	Dump body (F350)	260 miles[3]	$0.74/mile	192.40	
	Skid-Steer loader	5 hours[4]	$13.97	69.85	
	Labor		all @ $20/hour		
	Equipment operating	45 hours		900.00	
	Set-up/take-down	14.5 hours[5]		290.00	
	Travel time	17.33 hours[6]		346.60	
	Skid-steer operating	5 hours[4]		100.00	
Landfilling (crew of 1)	Stake body truck	275 miles[7]	$0.59/mile	162.25	
	Labor		all @ $20/hour		
	Loading debris	21.4 hours[8]		428.00	
	Travel	9.2 hours[9]		184.00	
	Tip fees	75 cubic yards[8]	$12/cubic yard	900.00	
Total				**3,921.85**	**196**
Maximum Number of Houses Served (per year) ……… 250[4]					
Cost for service (per house) ………………………….. $784.37					

Assumptions

1. Fifteen site visits per week (5 custom sites and 10 production sites, i.e., all in the same development); all are 2000 square foot homes generating 60 cubic yards of construction debris (of which 45 cubic yards are grind-able, 15 are hauled to landfill); each house is serviced three times during construction; and 100% operating efficiency.
2. Fifteen site visits per week; grinding 15 cubic yards per visit; and 10 cubic yards per hour [(15 visits/wk x 15 cy/visit)/ 10 cy/hr = 22.5 hrs/wk].
3. A weekly route consisting of: travel to and from storage shop (10 trips @ 10 miles each); travel from site to site (10 trips @ 10 miles each); and travel to drop-off processed material from custom sites (5 @ 10 miles each) and 10 drop-offs from production sites (@ 1 mile each)
[(10 x 10) + (10 x 10) + (5 x 10) + (10 x 1) = 260 miles].
4. One hour per house to spread the processed material on site; 15 site visits per week; 50 weeks per year; and three visits per house
[(15 visits/wk x 50 wks/yr)/ (3 visits/house) = 250 houses; and [(250 houses/yr x 1 hr/house)/ (50 wks/yr) = 5 hrs/wk].
5. Five daily set-up and five daily take-downs @ 20 minutes each; set-up and take-down at each of the six custom sites @ 20 minutes each; and two workers
[(5 + 5 + 6 + 6) x 0.33 hours) x 2 workers = 14.5 hours]
6. 260 miles traveled @ 30 miles per hour; and two workers [(260 miles x 2 workers)/ 30 miles/hr = 17.33 hours].
7. A weekly route consisting of: travel to and from storage shop (10 trips @ 10 miles each); travel from site to site (10 trips @ 10 miles each); and travel from sites to landfill/transfer station (7.5 trips @ 10 miles each) [(10 x 10) + (10 x 10) + (7.5 x 10) = 275 miles].
8. 75 cubic yards per week (15 visits @ 5 cubic yards each); debris loaded onto truck @ 3.5 cubic yards/hour [(75 cy/wk)/ (3.5 cy/hr) = 21.4 hrs/wk].
9. 275 miles traveled @ 30 miles per hour [(275 miles)/ (30 miles/hr) = 9.2 hours].
10. Unit costs are based on estimates presented in Appendix B, adjusted for annual use.

C3 - Estimated Cost of Conventional Landfilling
Serviced by Clean-Up Service[1]

Service			Cost ($)		
Task	**Vehicle/Item**	**Use per week**	**Unit Cost[6]**	**Weekly**	**Annua**
Landfilling (2 crews of 1)	Stake truck	320 miles[2]	$0.53	169.60	
	Dump body (F350)	320 miles[2]	$0.62	198.40	
	Labor		all @ $20/hour		
	Loading Debris	62.8 hours[3]		1,256.00	
	Travel	21.33 hours[4]		426.40	
	Tip fees	220 cubic yards[5]	$12/cubic yard	2,640.00	
Total				**4,690.40**	**234,52**
Maximum Number of Houses Served (per year) …….. 183[6]					
Cost for service (per house) ……………………. $1,281.53					

Assumptions

1. Service for both custom and production builders; 2000 square foot homes generating 60 cubic yards of construction debris each; 11 site visits/week; 10 cubic yard capacity in both trucks; and 100% operating efficiency.
2. A weekly route consisting of: travel to and from storage shop to sites (10 trips @ 10 miles each); trips to landfill/transfer station (11 loads @ 20 miles roundtrip) [(10 x 10) + (11 x 20) = 320 miles].
3. Eleven site visits per week; 10 cubic yards per visit; manual loading of construction debris onto truck at 3.5 cubic yards/hour; and two workers, i.e., two crews of one [(11 visits/week x 10 cubic yards/visit x 2 workers)/ (3.5 cubic yards/hr) = 62.8 hours].
4. 320 miles @ 30 miles per hour; and two workers [(320 miles x 2 workers)/ (30 miles/hr) = 21.33 hours].
5. 11 site visits per week; 10 cubic yards each; and two vehicles) [11 visits/wk x 10 cy/visit x 2 trucks = 220 cubic yards/wk].
6. 220 cubic yards/week (see assumption #5); 50 weeks per year; and 60 cubic yards per house [(220 cubic yards x 50 wks/yr)/ (60 cy/house) = 183 houses/yr].
7. Unit costs are based on estimates presented in Appendix B, adjusted for annual use.

C4 - Estimated Cost of Conventional Landfilling
Serviced by roll-off truck and dumpsters[1]

Service			Cost ($)		
Task	**Vehicle/Item**	**Use per week**	**Unit cost**[6]	**Weekly**	**Annual**
Landfilling	Roll-off truck	650 miles[2]	$1.05/mile	682.50	
	Roll-off boxes	2000 hours[3]	$0.17	340.00	
	Labor Pick-up/travel	40 hours	$20/hour	800.00	
	Tip fees	900 cubic yards[4]	$12/cubic yard	10,800.00	
Total				**12,622.50**	**631,125.00**
Maximum Number of Houses Served (per year) …….. 750[5]					
Cost for service (per house) ………………………. $841.50					

Assumptions

1. Service for both custom and production builders; one roll-off truck with use of 30 yard dumpsters; 2000 square foot homes generating 60 cubic yards of construction debris; and 100% operating efficiency.
2. A weekly route consisting of: travel to sites (six per day @ 10 miles each); travel to landfill/transfer station (six per day @ 10 miles); and return to shop (1 trip @ 10 miles); and five days/week [((6 + 6 + 1) x 10) x 5 = 650 miles.
3. Fifty roll-off dumpsters; and 40 hours/week [50 x 40hrs = 2000 hours].
4. Six daily pick-ups; 30 cubic yard roll-offs; and five days/week [6 pick-ups/day x 30 cy/pick-up x 5 days = 900 cubic yards].
5. 900 cubic yards per week (see assumption # 5); 50 weeks per year; and 60 cubic yards per house [(900 cy/wk x 50 wks/yr)/ (60 cy/house) = 750 houses].
6. Unit costs are based on estimates presented in Appendix B, adjusted for annual use.

C5 - Cost Comparison of Services: With Pilot Project Conditions

Service Type	Annual Costs ($)				Maximum # of houses served (per year)	Cost for service (per house)
	Machine	Labor	Tip Fees	Total		
Grinding for production builders only	39,719	121,466	60,000	221,185	333	$ 664
Grinding for production and custom builders	38,662	112,430	45,000	196,092	250	$ 784
Landfilling with Clean-Up service	18,400	84,120	132,000	234,520	183	$ 1,282
Landfilling with Roll-off trucks & dumpsters[1]	51,125	40,000	540,000	631,125	750	$ 841

C6 - Cost Comparison of Services: With Lower Tipping Fees[1]

Service Type	Annual Costs ($)				Maximum # of houses served (per year)	Cost for service (per house)
	Machine	Labor	**Tip Fees**	Total		
Grinding for production builders only	39,719	121,466	**30,000**	191,185	333	$ 574
Grinding for production and custom builders	38,662	112,430	**22,500**	173,592	250	$ 694
Landfilling with Clean-Up service	18,400	84,120	**66,000**	168,520	183	$ 921
Landfilling with Roll-off trucks & dumpsters[1]	51,125	40,000	**270,000**	361,125	750	$ 481

1. Assumes tipping fees of $6/cubic yard (pilot project tipping fees were $12/cubic yard).

C7 - Cost Comparison of Services: With Lower Labor Rates[1]

Service Type	Annual Costs ($)				Maximum # of houses served (per year)	Cost for service (per house)
	Machine	**Labor**	Tip Fees	Total		
Grinding for production builders only	39,719	**87,016**	60,000	186,735	333	$ 561
Grinding for production and custom builders	38,662	**84,710**	45,000	168,372	250	$ 673
Landfilling with Clean-Up service	18,400	**42,060**	132,000	192,460	183	$ 1,052
Landfilling with Roll-off trucks & dumpsters[1]	51,125	**40,000**	540,000	631,125	750	$ 841

1. Assumes a labor rate of $10.00/hour for debris-loading tasks, i.e., loading grinder and stake body truck for landfilling.

C8 - Cost Comparison of Services: With Longer Travel Distances[1]

Service Type	Annual Costs ($)				Maximum # of houses served (per year)	Cost for service (per house)
	Machine[2]	Labor	Tip Fees	Total		
Grinding for production builders only	39,719	121,466	56,880	218,065	**316**	$ 690
Grinding for production and custom builders	38,662	112,430	39,060	190,152	**217**	$ 876
Landfilling with Clean-Up service	18,400	84,120	96,000	198,520	**133**	$ 1,493
Landfilling with Roll-off trucks & dumpsters[1]	51,125	40,000	360,000	451,125	**500**	$ 902

<u>Assumptions</u>

1. A weekly route consisting of the following travel distances: 20 miles from shop to sites; 20 miles from site to site (for custom sites); and 40 mile roundtrips to landfill/transfer station.
2. Machine costs have been kept the same in this scenario to clarify the presentation. Although machine costs would be affected by longer travel distances and lower unit costs, the affect would be modest relative to the change in the number of houses served and the corresponding tipping fees.

APPENDIX D - EDUCATIONAL FACT SHEETS
(HOME BUILDERS, HOME BUYERS)

Appendix D

D1 - Guidelines for Land-Application of Processed Wood, Gypsum Wallboard, and Cardboard

This document provides guidelines for the on-site reuse of construction wood scraps, gypsum wallboard cut-offs and scrap cardboard generated during construction activity. These guidelines suggest the method of processing to prepare the materials for reuse, and offers guidelines for the land-application of the processed material. An accompanying document entitled *Land-Application of Construction Scrap: A Fact Sheet For Home Buyers* introduces the environmental issues related to this method of construction waste management to address the concerns of homeowners and their neighbors.

Processing the Material

Allowable material types. Only the materials listed below in the "Allowed" column are to be processed and land-applied. All other construction materials, scrap or otherwise, are not permitted to be processed or land-applied.

Material Types	Allowed	Prohibited	Required Particle Size
WOOD			
• solid sawn material (2x4s, etc)	●		minus 2-inches
• engineered wood products (OSB, plywood, I-joists, etc)	●		minus 2-inches
• painted		●	
• treated		●	
GYPSUM WALLBOARD			
• standard	●		minus 1-inch
• painted		●	
• type X		●	
• moisture resistant		●	
CARDBOARD			
• standard corrugated	●		minus 2-inch
• wax-coated		●	
ALL OTHER MATERIALS		●	

Equipment. Efforts should be made to reduce the amount of air-borne particulate generated during the grinding process, e.g., a water-misting/spraying devise. Nails or other metal in wood waste must be removed using magnets or other removal methods.

Construction wood scraps.

Wood waste is generated during new home construction at a rate of approximately 1.5-2 pounds per square foot of floor area. A 2,000 square foot home, for example, will generate about 3,500 pounds of wood waste, which is approximately 5-6 cubic yards after processing (assuming a 50 percent volume reduction). This amount of wood chips will provide a 2-3 inch layer for approximately 700-800 square feet. Effective uses for wood chips include the following:

Guidelines For Land-Application, continued

Road stabilization. Wood chips provide strength and cohesion to the driving surface, and promote the drainage of water away from the driving surface. The primary characteristic required is that wood waste be either chips or slivers with a minimum of fines. The presence of too many fines decreases strength or adhesion, and inhibits water drainage.

Erosion control. Wood chips can be used to stabilize soil while development is under way and can provide excellent erosion control on non-active sites as well. The use of wood waste for erosion control is limited to applications where degradability is desirable. Examples include:

- spread on road shoulders, or other areas where heavy equipment is used;
- temporary low-flow drainage swales;
- used in months too hot, dry, or cold to establish vegetation;
- in areas where vegetation is not wanted; and
- in areas of bare soil needing protection.

Landscaping mulch. Wood chips can be stockpiled and used after construction to mulch landscape beds, shrubs, and islands around trees. Landscape mulch is used as a ground cover material to control weeds, prevent moisture loss in soil, and for aesthetic purposes. In these applications, nitrogen can be added (20-30 pounds per acre) to aid decomposition. This is typically applied in a manner similar to fertilizer, e.g., with a push cart.

Protecting tree roots. One pass by one vehicle can compact the soil by 75 percent, crushing shallow roots and preventing water infiltration. Tree roots can be protected from damage and soil compaction by mulching over the root zone. Spread a 10 to 12 inch layer of wood chips over the portion of the root zone to lessen the impact of heavy equipment.

Gypsum Wallboard.

Cut-off scraps of gypsum wallboard generated during new home construction are generated at a rate of approximately one pound per square foot of floor area. The scrap drywall should be clean, i.e., no paint, no type X or moisture-resistant board, pulverized to a minus one inch size, and spread evenly around the site up to a range of 8 tons per acre. The table below can be used a guide to determine appropriate application rates.

Amount of pulverized gypsum wallboard		Minimum "Tillable" Land (square feet)
House Size[1] (square feet)	Size of pile[2] (cubic yards)	
1,250	3 - 3.5	3,400 Square feet or 1/13 acre
1,500	3.5 - 4	4,100 SF or approx 1/11 acre
2,000	5	5,445 SF or 1/8 acre
2,500	6 - 7	6,800 SF or approx 1/6 acre
3,000	7.5 - 8	8,200 SF or 1/5 acre
3,500	8.5 - 9	9,525 SF or ¼ acre

1. Based on a waste generation rate of one pound per square foot of floor area.
2. Based on a volume-weight conversion of 400 pounds/cubic yard, or 5 cubic yard/ton.

D2 - Land-Application of Construction Scrap
A Fact Sheet For Home Buyers

This document introduces the environmental benefits associated with this method of construction waste management to address any concerns of homeowners and their neighbors. This fact sheet also briefly explains the methods used by home builders to prepare and land-apply the materials.

What is being done?

- *Land application of wood chips.*

Wood chips are being used to control erosion (the wearing away of the land surface) while construction is underway. Adding a material such as chipped wood provides strength and stability to soft or muddy driving surfaces, and promotes the drainage of water away from the driving surface. The use of wood chips for erosion control is limited to areas where decomposition, or the breaking down of the wood, is desirable, such as under grass, gardens or bushes.

- *Land application of pulverized gypsum wallboard (drywall).*

Research has demonstrated that the beneficial effects of pulverized drywall waste are nearly identical to those of agricultural grade gypsum. Gypsum improves plant growth on a variety of soils due to improved soil structure and root penetration (particularly in clayey soils), and an increase in available calcium and sulfur.

Why is this being done?

- *Helps disturbances at the site*

The grading, trenching, and excavation of construction activity disturbs the natural site - soils are often compacted, soil structure can change, and the natural drainage patterns can change as well. Land applying these materials in this fashion can offer beneficial solutions to these common and often unavoidable consequences of building a home.

- *Conservation of landfill space*

The construction of a 2,000 square foot home will generate approximately four tons of debris, all of which is typically disposed of in landfills. Wood, drywall and cardboard typically comprise approximately 75 percent of this waste stream, and in many areas of the country there are limited reuse or recycling options for these materials (especially wood and drywall). On-site processing and application of these three materials can be a cost-effective and environmentally friendly alternative to conventional landfilling.

Do these materials pose any threat to the local water supply, or grass and plant growth?

No. Guidelines for the application of these materials have been prepared with the approval of the Indiana Department of Environmental Management. The materials being land-applied are clean, non-toxic, standard construction materials that have not been chemically treated or painted.

Land-Application of Construction Scrap, continued

Why hasn't this been done before?
This particular waste management technique is new. The equipment required to do this has only recently become available.

Do I need to do anything differently as a home owner?
No. In fact, wood chips can be used as a mulch for landscape beds, shrubs, and islands around trees. Landscape mulch is used in this fashion as a ground cover material to control weeds, prevent moisture loss in soil, and for aesthetic purposes. In these applications, nitrogen can be added (20-30 pounds per acre) to aid decomposition. This is typically applied in a manner similar to fertilizer, e.g., with a push cart.