Orange County, Florida
Seminole County, Florida

Innovative Drywall Recycling Grant

June 1, 2003

Prepared by R.W. Beck SCS Engineers
Orange County Innovative Recycling Grant

EXECUTIVE SUMMARY

Florida Department of Environmental Protection Grant # IGO-06
Development of Drywall Processing

In January 2001, Orange County entered into an Innovative Recycling Grant Agreement with the Florida Department of Environmental Protection (FDEP) for the purpose of drywall processing development. Orange County partnered with Seminole County and served as the lead county for this regional innovative grant. FDEP had previously awarded three other innovative grants that focused on drywall and its unique disposal and recycling challenges. The primary goal of the Orange County grant was to continue the collection and dissemination of data on drywall recycling technologies and opportunities. The very nature of an innovative grant requires that the recipients must be flexible in their efforts in order to adjust to unknown factors. This was the case with the Orange County innovative grant that made program modifications throughout the grant period, which was extended through May 15, 2003.

Drywall as a percentage of the C&D waste stream in Florida will increase if the state continues to experience high levels of growth and growth related construction. In addition to realizing savings in capacity at a landfill, the other primary incentive for establishing a feasible drywall recycling program is the reduction or elimination of odors caused by the decomposition process. There is a viable future for drywall recycling efforts, but long-term success for this type of program depends on overcoming critical obstacles and meeting the inherent needs of a recycling program. The four main obstacles that face any drywall recycling program are: 1) low cost of raw materials, 2) low disposal costs 3) barriers to an efficient method of separation and collection, and 4) processing costs.

The first obstacle is the low cost of virgin rock gypsum and synthetic gypsum. These raw materials are relatively inexpensive and the low cost makes it difficult for recycled drywall to compete for the end markets on a per ton basis.

The second obstacle is the low disposal tipping fees. There is little incentive to recycle if it requires more time and money than standard disposal methods. Convenient and inexpensive disposal sites are in a better position to compete for drywall than a recycling facility.

The third obstacle is the establishment of an efficient separation and collection method. The initial intent of the grant program was to obtain drywall from source separated sites, which required the drywall to be placed in a separate container at the construction sites. This process requires a fundamental system change to the current practice of commingling all construction debris in one container. In addition, utilizing two containers for construction debris results in additional charges for container transport. Changing behaviors and common practices requires an enormous amount of
education and lead time. Despite the incentive of free recycling for segregated drywall loads, there was limited participation from the commercial haulers due to the concern about the temporary status of the program, the hauling costs, and the long term education needs for the builders and crews. Based on those barriers to construction site separation of drywall, disposal site separation was then initiated for evaluation. Processes for mechanical and manual separation of drywall from mixed C&D loads were developed at both the Orange County Landfill and the private Republic 545 Landfill. These processes showed that drywall can successfully be separated from mixed loads.

The fourth obstacle is related to replacing existing raw material sources with recycled material that is competitive in cost and acceptable to the end markets. Materials were processed at both the Orange County Landfill and Republic 545 Landfill utilizing a trommel screen. The screen process produces a consistent size end product while at the same time removes most of the paper backing. Between the two sites, four processing events were held and the end markets (including NutriSource, Florida Crushed Stone and US Gypsum) had positive feedback about the quality of the final product. The applications for recycled drywall include soil amendments for crops, element in portland cement, and new drywall. Since the end markets make purchasing decisions on quality and cost, it is difficult to compete with the lower processing costs of raw or synthetic gypsum.

This grant built upon the knowledge gained from the previous innovative drywall grants and continued the momentum of interest in drywall recycling. Additionally, the drywall recycling program brought public and private sectors together to work on developing long term solutions to the issue of drywall in the waste stream. As a result of this project, the Republic 545 Landfill has plans to continue with their drywall recycling program and further develop their relationships with the end markets. New West Gypsum based out of Ontario has also begun looking at the Florida market for recycled drywall and met with the grant project team. This grant also achieved its goal of disseminating information, through a variety of channels. Articles about the project were carried in local and national magazines and trade journals. A presentation was conducted at a national conference of solid waste professionals and another presentation is scheduled at the Recycle Florida Today Annual Conference in June 2003.

Through the different innovative grants it is clear that a successful and economically viable program must produce a material that can competitively meet the cost and quality requirements of the end markets, have an efficient and cost effective method of separation and collection, and ensure a reliable source of material. It is also apparent that given the economic factors of drywall recycling, a viable and sustainable program would require non-monetary incentives. An example of this is the 545 Landfill in Orange County where limited capacity and odor problems were two of the motivating factors for the implementation of a drywall recycling program.
# Orange County
## Seminole County
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This report has been prepared for the use of the client for the specific purposes identified in the
report. The conclusions, observations and recommendations contained herein attributed to
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In recent years, gypsum drywall has become a material of particular interest within the state of Florida. This interest has been spurred for two primary reasons.

- Drywall decomposition has been blamed for severe odor problems occurring at several construction and demolition debris landfills in the state.
- As a result of Florida’s rapid growth, increased focus has been placed on the ever-growing construction and demolition debris (C&D) stream. Based on research by the University of Florida, drywall is believed to represent approximately 13 percent of the overall C&D stream.

As a result of the issues above, the Florida Department of Environmental Protection (FDEP) has placed increased focus on investigating methods to eliminate drywall from the C&D disposal stream. Over the past several years, the FDEP has awarded four Innovative Recycling Grants to explore methods for diverting drywall from the waste stream. These studies have involved researching various collection and processing methods and evaluating various end-market alternatives. Table 1-1 below provides a summary of the FDEP Innovative Recycling Grants associated with drywall that have been conducted to date.

<table>
<thead>
<tr>
<th>County Grant Recipients</th>
<th>Primary Markets Evaluated</th>
<th>Grant Fiscal Year Awarded</th>
</tr>
</thead>
<tbody>
<tr>
<td>Citrus, Putnam</td>
<td>Portland Cement</td>
<td>1998/1999</td>
</tr>
<tr>
<td>New River Solid Waste</td>
<td>Agriculture, Road Stabilization</td>
<td>1998/1999</td>
</tr>
<tr>
<td>Authority*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Okaloosa</td>
<td>Agriculture</td>
<td>1998/1999</td>
</tr>
</tbody>
</table>

* The New River Solid Waste Authority is a joint solid waste utility formed by Baker, Bradford, and Union Counties.

Bold = lead county, Regular = partner county

Due to the infancy of drywall recycling within the state of Florida, the FDEP encouraged each of the sponsor counties that were awarded grants during the 1998/1999 fiscal year to work collaboratively and share project successes and failures such that each of the three projects could benefit from the others. In supporting this goal, the three sponsor counties also agreed to develop a joint report (as required by FDEP Innovative Recycling Grant requirements) at the conclusion of the project (instead of three separate project reports). The joint report was developed by the
University of Florida’s Department of Environmental Engineering Sciences under the direction of Dr. Tim Townsend. Technical review was provided by staff from each of the sponsor counties as well as R.W. Beck, Inc. and Jones Edmunds and Associates (consulting engineers to the counties). This joint report represents one of the most comprehensive discussions of drywall generation, collection, processing, and marketing ever developed. Several sections of the joint report are included within the body and appendices of this report in order to provide those readers that desire more detailed information on certain issues with additional information.

The results of the three 1998/1999 Innovative Recycling Grants targeting drywall demonstrated some success in the collection, processing, and marketing of scrap drywall. Like most recycled commodities, the over-riding barrier identified by the three studies was economics. The costs associated with collecting, processing, and transporting recycled drywall to markets at a cost equal to or less than the cost of virgin rock gypsum proved challenging. One of the principal conclusions of the joint report was that in order to economically collect and process drywall, collection activities must be located in an area where sufficient quantities of scrap drywall could be collected to develop economies of scale.

As a result of the previous three studies, it was recommended that the FDEP should investigate drywall recycling efforts in a more populated area with more rampant construction activity. The FDEP then awarded Orange and Seminole Counties with an Innovative Recycling Grant during the 1999/2000 grant cycle (hereinafter called the Orange/Seminole Grant). As shown in Table 1-2 below, Orange and Seminole Counties collectively are significantly larger and have substantially more construction activity (measured in terms of number of residential building permits issued) than any of the other counties where drywall recycling grants were implemented in the past.

### Table 1-2
Comparison of Market Size by Grant Recipient

<table>
<thead>
<tr>
<th>County Grant Recipients</th>
<th>2000 Population of Service Area (^{[1]})</th>
<th>No. of Residential Building Permits Issued during 2000 (^{[2]})</th>
<th>Construction Cost during 2000 (^{[2]})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Citrus, Putnam</td>
<td>191,291</td>
<td>1,362</td>
<td>$93,609,264</td>
</tr>
<tr>
<td>New River Solid Waste Authority</td>
<td>62,163</td>
<td>197</td>
<td>$16,251,937</td>
</tr>
<tr>
<td>Okaloosa</td>
<td>173,450</td>
<td>1,079</td>
<td>$177,457,453</td>
</tr>
<tr>
<td>Orange, Seminole</td>
<td>1,307,994</td>
<td>9,064</td>
<td>$1,477,050,420</td>
</tr>
</tbody>
</table>


This report provides additional background on the generation and disposal of gypsum drywall in Central Florida. It also discusses the drywall collection, separation, processing, and marketing the project team performed as part of the Orange/Seminole County Grant project.
Section 2
BACKGROUND ON GYPSUM DRYWALL

(This Section was taken with permission from the report “Recycling of Discarded Gypsum Drywall in Florida” by Timothy G. Townsend, Allison H. Barnes, Kimberly M. Cochran, and Jenna Jambeck Carlson of the University of Florida’s Department of Environmental Engineering Sciences.)

2.1 The Mineral Gypsum

Gypsum is a non-metallic mineral composed of calcium sulfate (CaSO\textsubscript{4}) and water (H\textsubscript{2}O). Gypsum is also called hydrous calcium sulfate (CaSO\textsubscript{4}.2H\textsubscript{2}O). Natural gypsum deposits formed as a result of evaporating seawater from ancient seabeds. Today, gypsum is mined from these deposits as a raw material for many different manufacturing, industrial, and agricultural uses. The United States leads the world in gypsum mining and production with 18% of the global output. According to the US Geological Survey (USGS), the majority of the gypsum mined in the U.S. (72%) comes from the following states (in descending order): Oklahoma, Iowa, Texas, Michigan, California, Nevada, and Indiana. A number of industrial processes produce synthetic gypsum as a byproduct, including phosphate fertilizer production and desulfurization of combustion gases. Figure 2-1 presents the distribution of the raw gypsum supply in the United States. The majority comes from mines in the U.S., however a fraction is imported (primarily from Canada, Mexico, and Spain), and another fraction is derived from byproducts of the industrial processes listed above.

Figure 2-1
Gypsum Supply in the U.S.

![Gypsum Supply in the U.S.](image)

Processed gypsum is classified as calcined (part of the water is driven off) or uncalcined. Calcined gypsum is used in the production of drywall and plaster of paris. Uncalcined gypsum is used for portland cement manufacture, agriculture, and fillers in consumer products. According to the USGS, the amount of gypsum products produced in the United States amounts to more than 37 million metric tons. Cement production accounted for more than five million metric tons, and agricultural applications accounted for more than three million metric tons. The remainder was primarily used for drywall manufacturing. Figure 2-2 presents the major gypsum markets and their relative distribution. Federal funding authorized in 1998 for road repair and construction will likely increase the need for gypsum in cement production. The average price per ton of crude uncalcinated gypsum is $7.20, while calcined gypsum is priced at $18.00 per ton on average. The United States produced 19,400,000 tons of calcined gypsum in 1998, valued at $302 million. Florida alone produced 1,230,000 tons, valued at $26.6 million.

Figure 2-2
Gypsum Sold for Production and Use in the U.S.


### 2.2 Gypsum Drywall

Gypsum is naturally fire resistant, which makes it a popular building material. There are 65 drywall-manufacturing plants in the United States that produce and sell 29.1 billion square feet of drywall per year. The drywall manufacturing process begins with the mined gypsum. After the gypsum is transported from the mines, it is crushed. Any rock larger than two inches in diameter is size reduced. The crushed gypsum is fed into a "rock dryer," a kiln that evaporates any moisture on the rocks. Then it is
ground into a fine powder, which is often called “land plaster.” The wallboard manufacturing process uses calcined gypsum. The calcination process involves heating the “land plaster” (hydrous calcium sulfate), removing approximately three-quarters of the water to form calcium sulfate hemi-hydrate (CaSO4.1/2H2O). The powder is heated to remove 75% of the water that makes up the actual chemical structure of the gypsum. This process turns the powder into stucco, a very dry powder that will harden quickly when mixed with water. The stucco is fed into a pin mixer and mixed with water and other ingredients, depending on the type of drywall being made. This slurry is spread onto a moving continuous sheet of paper, then sandwiched with a top paper, forming the wallboard. This continuous sheet of wallboard travels on conveyor belts for four minutes in order to allow the slurry to harden. It is then cut into panels and sent to a kiln for final drying. It is trimmed to the exact length and bundled, ready for shipment. Figure 2-3 summarizes the drywall manufacturing process.

Manufactured Fire Resistant (Type X) Drywall
Figure 2-3
The Drywall Manufacturing Process at a Typical Gypsum Plant

1. Mine
2. Fundamental crushing
3. Secondary crushing
4. Calciner
5. Raymond Mill
6. Tube Mill
7. Plaster additives
8. Plaster Mixer
9. Packer
10. Board Additives
11. Board Mixer
12. Master Roll
13. Drilling & Blasting
14. Printer
15. Knife
16. Inverter
17. Drying Kiln
18. Bundled & Piled
19. Bundled & Piled
20. Plaster Additives
21. Plaster Mill
22. Bundled & Piled
23. Distribution

Source: U.S. Gypsum, 1999
Drywall comes in many different types and sizes to meet very specific needs in a residential home or commercial building. Figure 2-4 presents the relative amounts of prefabricated (drywall) products that are produced from gypsum. Regular gypsumboard is the most common type of drywall produced followed by Type X, which is fire resistant. Other types include water resistant board and drywall produced specifically for mobile homes. The most common types of drywall produced and their applications are summarized in Table 2-1.

**Figure 2-4**
Prefabricated Products Made from Gypsum

![Diagram showing the relative amounts of prefabricated products made from gypsum. Regular gypsumboard accounts for 59%, Type X gypsumboard for 28%, and other types for varying percentages.](image-url)
## Section 2

### Table 2-1
Typical Drywall Types and Applications

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regular Gypsum Drywall</td>
<td>Used for interior walls and ceilings, with sound and fire resistant properties depending on the thickness and assembly</td>
</tr>
<tr>
<td>Fire Resistant (Type X)</td>
<td>Used in ceilings, floors and interior walls because of the non-combustible core</td>
</tr>
<tr>
<td>Water Resistant</td>
<td>Used for backing in bathroom and shower areas</td>
</tr>
<tr>
<td>Type X Water Resistant</td>
<td>Both fire and water resistant</td>
</tr>
<tr>
<td>Wide Board</td>
<td>Used for large applications such as ceilings and eliminates the need for a filler strip</td>
</tr>
</tbody>
</table>

Source: U.S. Gypsum, 1999

### 2.3 Gypsum Drywall in Construction and Demolition Waste

C&D waste consists of building related waste (construction, demolition and renovation), roadway related waste, land-clearing debris, and inert debris waste. Drywall is a typical component of the building related waste. Construction debris consists primarily of scraps from trimming and cutting pieces of wood, drywall, roofing material and masonry work. Demolition waste can be 20 to 30 times the amount of construction waste generated on a per building basis (U.S. EPA, 1998). Renovation waste is a combination of both demolition and construction waste. Typically, C&D waste is sent to a landfill or a materials recovery facility (MRF).

The amount of drywall in the building related C&D waste stream may range from 7% to 76%, depending on whether the waste comes from construction, demolition or renovation activities. The percentage of drywall in the C&D waste stream will vary by size and type of the building and construction materials used. No National or statewide estimate of C&D waste composition currently exists, but waste composition studies have been performed on different C&D waste streams. This section further examines the percentages of drywall generated from these building related activities.
2.3.1 Drywall in Construction Debris

Construction debris is generated from residential and non-residential building related activities. According to the U.S. Environmental Protection Agency (EPA), residential new construction comprises 5% and non-residential comprises 3% of the building related C&D waste generated in the U.S. as a whole. This percentage is likely higher in Florida because of the state’s rapid growth and relatively new infrastructure. Waste audits characterizing the composition of residential and non-residential new construction debris have been performed by several entities including the National Association of Homebuilders (NAHB) Research Center, the Metropolitan Service District in Portland, Oregon, the Metro Waste authority in Des Moines, Iowa, Cornell University and the University of Florida.

The NAHB conducted waste assessments of four residential construction sites. These sites were in Largo, Maryland; Anne Arundel County, Maryland; Portland, Oregon; and Grand Rapids, Michigan. The percentage of drywall in the waste stream from the residential study ranged from 24% to 31%. A series of audits were undertaken by the Metropolitan Service District in Portland, Oregon (METRO). Assessments took place at several residential and non-residential construction, demolition and renovation sites. The percentage of drywall waste from the residential audits ranged from 11% to 28%.

Drywall was found to be 16% of the waste from residential construction and 7% from non-residential construction in a 1995 study performed in Des Moines, Iowa by the Metro Waste Authority and Gershman, Brickner & Bratton, Inc. (GBB). A waste composition study of construction sites in Alachua County, Florida found residential construction to contain 30% drywall and non-residential construction to contain 11%. The pie charts in Figure 2-5 present the average waste compositions of the four sites examined by the NAHB, the average of the three sites examined by METRO, and both the residential and non-residential waste audits performed in Iowa.
Section 2

Figure 2-5
Construction C&D Waste Compositions

Average New Residential C&D Waste Composition for Four Sites (NAHB, 1995)
- Wood: 43%
- Drywall: 27%
- Textiles: 0.3%
- Other Packaging: 1%
- OCC: 5%
- Asphalt: 1%
- Brick: 3%
- Metals: 2%

Average New Residential C&D Composition for Three Sites in Oregon (METRO, 1992-1995)
- Wood: 66%
- Drywall: 20%
- Concrete: 5%
- Cardboard: 1%
- Metal: 0%
- Misc: 8%

Residents New Construction Waste Composition by Weight in Iowa (Brickner, 1995)
- Wood: 44%
- Drywall: 16%
- Roofing: 6%
- Metal: 2%
- Plastic: 1%

Non-Residential Construction Waste Composition by Weight in Iowa (Brickner, 1995)
- Wood: 19%
- Metal: 9%
- Drywall: 7%
2.3.2 Drywall in Demolition Debris

Residential demolition debris comprises 15% and non-residential demolition debris comprises 33% (the largest fraction) of C&D waste produced from building related activities in 1998, according to the EPA. In that year, the EPA estimated that 19.7 million tons of residential demolition debris and 45.1 million tons of non-residential demolition debris are generated per year. As homes ending their life cycle are being demolished, more modern construction materials are entering the demolition C&D waste stream like drywall, treated wood and composite materials.

A C&D composition study focusing on demolition debris was completed by the Metro Waste Authority and GBB in Des Moines, Iowa. Both residential and non-residential buildings were assessed. Drywall was found to compose 10% of the residential and 20% of the non-residential demolition waste. A demolition contractor, R.W. Rhine, in Tacoma, Washington, performed waste audits on 19 non-residential demolition sites in the northwest area. The waste characterization from these combined demolitions, was composed of 41% drywall. In 1997, the NAHB Research Center performed a deconstruction project (the Riverdale Case Study). A multi-family (4-plex) building was systematically dismantled for the purpose of recovering and recycling the demolition waste. Drywall composed 17% of this waste stream. The pie charts in Figure 2-6 present the waste compositions of the residential and non-residential demolition waste audits performed in Iowa, the combined waste composition of the 19 demolition sites in Washington and the waste composition from the Riverdale Case Study.
Figure 2-6
Demolition C&D Waste Composition

Residential Demolition Waste Composition by Weight in Iowa (Brickner, 1995)

- Wood: 33%
- Concrete: 22%
- Drywall: 10%
- Metal: 5%
- Roofing: 17%
- Other: 9%
- Brick: 4%
- Cardboard: 0.4%
- Plastic: 0.4%

Non-Residential Demolition Waste Composition by Weight in Iowa (Brickner, 1995)

- Wood: 25%
- Concrete: 32%
- Drywall: 20%
- Metal: 12%
- Roofing: 3%
- Wood: 25%
- Brick: 7%
- Cardboard: 1%

19 Industrial Demolition Projects in Northwestern America (U.S. EPA, 1998)

- Concrete: 66%
- Asphalt: 2%
- Scrap Iron: 5%
- Bricks: 1%
- Landfill Debris: 9%
- Wood: 16%
- Roofing: 0.8%

Riverdale Case Study: Multi-Family (4-Plex) Building Deconstruction (NAHB A, 1997)

- Concrete: 51%
- Drywall: 17%
- Roofing: 3%
- Bricks: 14%
- Misc: 1%
- Wood: 14%
- Rubble: 51%
2.3.3 Drywall in Renovation Debris

Renovation debris is a combination of C&D debris and is much more variable than either. Residential renovation waste comprises 23% and non-residential waste comprises 21% of the C&D waste generated from building activities. In 1998, the U.S. EPA estimated that 31.9 million tons of residential renovation debris and 28.04 million tons of non-residential renovation debris are generated per year.

The METRO Oregon C&D composition study also included a renovation waste audit. Drywall was found to comprise 76% of the waste generated from kitchen renovation activities. The C&D composition completed in Des Moines, Iowa performed by the Metro Waste Authority in 1995 also included renovation data. Drywall composed 16% of the C&D waste stream from a non-residential renovation. The pie charts in Figure 2-7 present the percent composition of the waste stream from both these renovation audits.

Figure 2-7
Renovation C&D Waste Composition

2.4 Environmental Impacts of Gypsum in Construction and Demolition Debris

A number of environmental issues are associated with the disposal of gypsum drywall in C&D debris landfills. These issues arise when gypsum drywall is subjected to certain conditions including an anaerobic environment, a specific pH range, and adequate moisture after disposal. In an unlined landfill, water from precipitation or groundwater intrusion allows calcium sulfate from the drywall to be released (leached) into solution, according to a study performed by the University of Florida. Aqueous sulfate is included in the secondary drinking water standards. Secondary drinking
water standards are not health-based, but were developed for aesthetic and taste conditions in water. Drinking water standards are used as groundwater protection standards in the state of Florida. Leaching of sulfate from drywall has the potential to exceed the groundwater protection standard for sulfate.

Another environmental issue is the generation and then release of hydrogen sulfide gas. Hydrogen sulfide is a toxic, colorless gas with a distinctive “rotten egg” odor. Many landfills throughout Florida and the United States have had complaints from surrounding residents about “rotten egg” odors coming from the landfill. In May of 1995, the St. Petersburg Times reported neighbors of the Sunset Landfill in Pasco County, Florida had problems associated with hydrogen sulfide. Residents near the landfill had been evacuated twice because of hydrogen sulfide odor problems. Hydrogen sulfide monitoring was completed at Pine Ridge Recycling and Disposal Facility in Orange County, Florida in response to complaints from residents concerning health and safety issues. Odor complaints were also made against G.E.L. Corp. C&D Recycling Facility in Volusia County, Florida and at an MSW landfill in Collier County, Florida.

The production of hydrogen sulfide occurs when calcium sulfate is reduced to the hydrogen sulfide gas. Sulfate reducing bacteria accept electrons to reduce sulfate and hydrogen sulfide is produced through the process shown below.

\[
\begin{align*}
\text{SO}_4^{2-} & \rightarrow \text{Organic Matter (e.g. Drywall paper backing)} & \text{Assimilatory sulfate reduction} & \rightarrow \text{H}_2\text{S}
\end{align*}
\]

The rate at which hydrogen sulfide is generated depends on the concentration of organic matter, concentration of dissolved oxygen in the leaching solution, the pH and the temperature.

### 2.5 Gypsum Drywall Regulations/Legislations

In an effort to compile the latest available information on current drywall legislation, programs, and processors, the Department of Environmental Protection or equivalent agency for each of the United States was contacted by the University of Florida in a study. In addition to the U.S., international agencies were also contacted to provide some insight into how other parts of the world are addressing the issue of drywall disposal and recycling.

#### 2.5.1 United States

To date, no U.S. state has banned the disposal of gypsum drywall in landfills. Some states do limit which landfills can receive gypsum drywall. In Washington, the definitions of demolition and inert wastes found in the “Minimum Functional Standards for Waste Handling” (ch. 173-304 WAC) excludes gypsum wallboard waste. This exclusion limits where wallboard waste may be sent for disposal. Wallboard may be only disposed of in landfills permitted to accept gypsum waste. New Mexico does not allow drywall to be disposed as “clean fill.” Tennessee has
proposed regulations concerning drywall disposal. Tennessee State Senator James Kyle has proposed legislation to prohibit drywall disposal in Class 3 and Class 4 landfills.

Two states, Nebraska and New Jersey, have regulations restricting drywall reuse. Use of drywall is prohibited in land improvement projects due to concerns about general groundwater contamination in Nebraska Title 132, Integrated Solid Waste Management Regulations, Chapter 2, Sections 002.01A and 002.01K. Use of drywall as a soil amendment is prohibited due to concerns about heavy metals in the paper of drywall in New Jersey regulations NJAC7:26-1.7 (g). Drywall is banned from land application in other states as well. In Oklahoma the recycling of any product as a land application is not allowed. Michigan has general recycling regulations; however, drywall recycling has not been approved to date. The State of Connecticut is currently drafting a guidance document for drywall recycling.

Other states do not have stringent guidelines for drywall disposal or recycling. In Kansas, drywall used at construction sites can be used on site as a soil conditioner. Kentucky, Maine, Florida and New Mexico allow drywall to be buried on site at construction sites. In addition, New Mexico allows drywall to be beneficially reused in soil treatment, sludge bulking, dirt and clay settling in turbid water, leaching sodium salt on salt treated roads, and odor reduction for animal waste. The State of New York has general beneficial reuse regulations with drywall reuse requiring approval on case specific basis. Reuse projects that have been approved previously include use in spill absorption, composting, calcium and sulfur additives in agricultural fields, new drywall, and plaster.

2.5.2 Canada

Some regions of Canada have instituted bans on the landfiling of gypsum drywall. Environment Canada, the Canadian version of the Environmental Protection Agency, does not have national legislation banning gypsum drywall from landfills. The bans are also not in place at the Provincial and Territorial level. A number of cities or districts have implemented bans. The most notable is the ban on landfiling gypsum drywall, instituted in 1990, by the Greater Vancouver Regional District. This ban was placed as a result of several landfills that experienced severe hydrogen sulfide odor problems. According to New Wast Gypsum, the ban was implemented, however, with the knowledge that a gypsum drywall recycling firm was under operation in the area. Other locations in Canada have implemented bans, including the city of Guelph in Ontario.
A successful drywall recycling program requires a reliable source of material. As stated previously, other drywall recycling programs in the state were unable to sustain themselves largely due to a lack of material. Orange and Seminole Counties are rapidly growing counties and are seen as large generators of C&D debris. This section of the report provides a summary of population, construction activity, and C&D disposal patterns in Orange and Seminole Counties.

3.1 Orange County

Orange County is located in eastern Central Florida with a 2001 population of 930,034. The County encompasses over 900 square miles of relatively flat terrain. The principal cities of Orange County include Orlando, Winter Park, and Ocoee. The Orange County economy is largely driven by tourism and service industries.

Like most of Florida, Orange County has experienced tremendous growth over the last 20 to 25 years. Between 2000 and 2001, Orange County ranked as Florida’s fastest growing county in terms of absolute population change, with a change of 33,960 additional persons. Figure 3-1 below demonstrates the population increase since 1970.

The population growth within the county has caused an increase in the need for housing. Figure 3-2 provides a summary of the residential building permits issued in Orange County (includes incorporated areas) from 2000 through 2002. Figure 3-3 provides a summary of commercial building permit activity in unincorporated Orange County since the 1999/2000 fiscal year.
Growth and the subsequent proliferation of building activity in Orange County has placed high demands on all of the County’s infrastructure – including transportation, waste/wastewater, school, and solid waste disposal systems. There are currently five landfills in the County permitted to accept construction and demolition debris. The two landfills that participated in this project were the Republic 545 Landfill in western
Orange County and the Orange County Landfill located in eastern Orange County. Table 3-1 below provides a summary of the existing C&D/Class III landfills in Orange County along with the estimated annual tons recycled and disposed by each.

Table 3-1
Fate of Material at Orange County C&D and Class III Landfills During 2000

<table>
<thead>
<tr>
<th>Landfill</th>
<th>Annual C&amp;D Tons Disposed</th>
<th>Annual C&amp;D Tons Recycled</th>
<th>Total Tons Managed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orange County Class III Landfill</td>
<td>211,917</td>
<td>13,862</td>
<td>225,779</td>
</tr>
<tr>
<td>Keene Road Class III Landfill</td>
<td>385,125</td>
<td>0</td>
<td>385,125</td>
</tr>
<tr>
<td>Republic 545 C&amp;D Landfill</td>
<td>403,699</td>
<td>43,322</td>
<td>447,021</td>
</tr>
<tr>
<td>Mid-Florida Materials C&amp;D Landfill</td>
<td>221,576</td>
<td>285,189</td>
<td>506,765</td>
</tr>
<tr>
<td>Pine Ridge C&amp;D Landfill</td>
<td>79,151</td>
<td>87,171</td>
<td>166,322</td>
</tr>
</tbody>
</table>

Source: FDEP Annual Report for a Construction and Demolition Debris Facility; Orange County Solid Waste Division

3.2 Seminole County

Seminole County is Orange County’s neighbor to the north. Seminole County has been largely considered a bedroom community to Orange County, however as a result of recent economic development efforts, the County has begun to develop a relatively significant economic base of its own. Seminole County is Florida’s twelfth largest county with a 2001 population of 377,960. Figure 3-4 below provides a graphical depiction of the growth in Seminole County’s population.

Figure 3-4
Historical Population Growth in Seminole County

Though Seminole County is not experiencing the sharp increase of building permit activity, building activity is steadily occurring and shows no sign of stopping.
Figure 3-5 below provides a summary of residential building permit activity in Seminole County (includes incorporated and unincorporated areas) since 2000. Nonresidential construction data was not available for Seminole County at the time this report was written.

![Seminole County Residential Building Permits](image)

**Figure 3-5**  
Seminole County Residential Building Permits*  

<table>
<thead>
<tr>
<th>Calendar Year</th>
<th>Number of Building Permits</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>3,000</td>
</tr>
<tr>
<td>2001</td>
<td>4,000</td>
</tr>
<tr>
<td>2002</td>
<td>2,000</td>
</tr>
</tbody>
</table>

Source: U.S. Census Bureau  
* Includes all incorporated and unincorporated areas

There are currently not any active C&D or Class III landfills within Seminole County. It is believed that most of the C&D debris generated in Seminole County is transported to Orange or Volusia Counties for disposal.
Perhaps the most important and challenging aspect of drywall recycling is finding an efficient method of separation and collection. This section of the report will discuss the program promotion, collection, and separation efforts performed by Orange County, Seminole County, and the Republic 545 Landfill in implementing the drywall recycling pilot project.

### 4.1 Stakeholder Participation and Program Promotion

Based on past efforts, the Counties were aware that initiating and sustaining a drywall recycling program would have to include participation from a number of stakeholders. A Technical Advisory Group (TAG) was formed for the purpose of: (1) educating those parties that might potentially be impacted or interested in the program, and (2) to obtain feedback from these individuals based on their knowledge and understanding of the construction and disposal business in Central Florida. The TAG included representatives from the following organizations:

- Orange County Solid Waste Division;
- Seminole County Solid Waste Division;
- County consultants;
- University of Florida Department of Environmental Engineering Sciences;
- FDEP;
- Local C&D waste haulers;
- Local C&D landfill operators;
- Drywall processors/recyclers from other regions in the U.S and Canada;
- Local general contractors; and
- End market representatives (cement, agriculture, and drywall).

A total of four TAG meetings were held over the duration of the project.

In addition to the TAG meetings, the project was promoted using the following methods:

- Development of flyers and promotional emails announcing free recycling for segregated loads of drywall;
Section 4

- Development and release of press releases that highlighted the results of program activities and described how other parties could get involved in the program;
- Contacting potential participants directly by phone to notify them of upcoming activities; and
- One-on-one meetings with waste haulers, building contractors, and other stakeholders.

4.2 Collection

There are two primary methods to collect drywall for recycling, source separation and disposal site separation. Both of these methods were piloted during the Orange/Seminole County Grant. The sections below provide a summary of the results of each pilot program as well as the advantages and disadvantages of each collection system.

4.2.1 Source Separated (Construction Site) Collection

4.2.1.1 Method

With source separation, drywall is separated from other types of construction debris at the construction site. Source separation generally entails a hauler placing a separate roll-off container (typically either 20 or 30 cubic yard containers), wire pen, or separate pile located specifically for drywall at the construction site. Drywall hangers or construction clean up crews place the scrap drywall in the drywall container or pile upon completion of the drywall installation. The drywall is then picked up by a solid waste hauler and delivered to the appropriate recycling/disposal location for processing.

In Florida, general contractors are responsible for the collection and disposal of the waste from a construction site. This does not lend itself to segregation as waste materials from various stages of construction are mixed together. In other areas of the country, drywall contractors (not the general contractors) are responsible for their own waste. This facilitates waste separation as most of the waste generated on a job site from the drywall contractor is drywall, with only a few contaminants.

4.2.1.2 Advantages/Disadvantages

Source separation of C&D recyclables is a systematic change to the C&D collection process in most areas of Florida and has a number of advantages and disadvantages with respect to drywall recycling. Table 4-1 provides a summary of each.
Table 4-1
Advantages and Disadvantages of Source Separation

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Efficient – eliminates need for downstream separation.</td>
<td>• Requires widespread education/system change – contractors and workers are not accustomed to separating on-site.</td>
</tr>
<tr>
<td>• Quality – if not contaminated, typically results in highest quality end-product.</td>
<td>• Adds to construction disposal costs.</td>
</tr>
<tr>
<td></td>
<td>• Space Requirements – requires another container, bin, or pile to be placed on site.</td>
</tr>
<tr>
<td></td>
<td>• Contamination – site workers often do not discriminate between disposal and recycling containers.</td>
</tr>
</tbody>
</table>

4.2.1.3 Results of Source Separation Program

For the source separation program, it was decided to utilize Orange County crew collection as well as encouraging the private sector C&D haulers in Orange County to participate in the program. With grant funds, the County purchased five roll-off containers to collect drywall-only loads using an existing County roll-off truck. Those loads collected by the County were not charged a collection or disposal fee. The County faced challenges during the collection of source separated drywall. The County roll-off truck was used for several purposes within the County’s Solid Waste Division (hence it was sometimes unavailable). In addition, there were accessibility and space constraint issues with the container placement at construction sites. Thus, this task proved to be more difficult than originally anticipated.

Upon locating several construction projects interested in participating in the program, Orange County placed roll-off containers at construction sites. The construction sites included the Orange County Convention Center expansion (a one million square foot construction project) and a Hampton Inn (a four-story hotel). The County pulled a total of eleven drywall roll-off containers weighing approximately 76.63 tons from these two projects alone.

In order to encourage the private sector hauling community to participate in the program, both Orange County and Seminole County announced that they would recycle at no charge segregated drywall loads brought to their disposal facilities. While several haulers found this offer attractive, others were concerned over the limited duration of the program. Some of the haulers expressed concern about spending the time and effort to educate their sales staff as well as their contractor customers only to have the program discontinued in the future. In addition, because disposal typically only represents about one third of the total cost of servicing a C&D roll-off container (with hauling being the other two-thirds), the zero tip fee did not provide enough of an incentive for many haulers to participate in the program. In total, private sector haulers delivered eight drywall loads weighing approximately 57.60 tons.
4.2.2 Disposal Site Separation/Collection

Based on the marginal success in convincing contractors and waste haulers to source separate scrap drywall, Orange County along with the Republic 545 Landfill decided to explore disposal site separation. Disposal site separation involves the manual or mechanical separation of drywall from mixed loads of C&D debris.

One of the motivating factors to explore disposal site separation was the fact that it appeared that drywall typically consumed an overwhelming portion (on the order of 70 to 80 percent by volume) of the contents of C&D loads where drywall was present. This was affirmed during the TAG meetings by contractors and waste haulers. It was believed that the high percentage of drywall in these loads would reduce the level of effort associated with removing the contaminants (generally consisting of joint compound buckets, cardboard, wiring, etc.) from the drywall loads.

It should be noted that the 545 Landfill had several motivating factors to participate in the program. First, the landfill had approximately 2 years of capacity left under its existing permit. Recycling a large fraction of the landfill’s incoming stream would most certainly extend the life of the landfill. Second, understanding that the landfill’s useful life was soon to be expiring, Republic had applied for a permit modification and zoning change in order to add approximately 30 feet of elevation to the landfill. In the midst of this permitting process, it was in Republic’s best interest to demonstrate the landfill’s commitment to recycling. Finally, the 545 Landfill had been experiencing some problems with odor, which is believed to be caused by decomposing drywall in the landfill. Recycling the drywall rather than disposing of it would help mitigate the odor problems.

4.2.2.1 Method

With disposal site separation, C&D loads were collected mixed with no special requirements placed on the contractor or waste hauler. Upon delivery to the solid waste disposal site, those loads that contained a high percentage of drywall were diverted to a separate area for manual or mechanical separation. In addition, large drywall pieces were manually or mechanically extracted from tipped loads in designated areas at the Class III cell.

4.2.2.2 Advantages/Disadvantages

The principal advantage of disposal site separation is that it places no special requirements on the contractor or the waste hauler and, therefore, does not require change to the current system of waste collection. Table 4-2 provides a summary of other advantages and disadvantages of disposal site separation.
Table 4-2
Advantages and Disadvantages of Disposal Site Separation

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ Easy implementation – No change to current system for contractors and haulers. No need for promotion, education, etc.</td>
<td>▪ Separation costs – Labor, time, and equipment are needed to sort the material.</td>
</tr>
<tr>
<td>▪ Allows for separation of other C&amp;D recyclables (wood, metals, etc.)</td>
<td>▪ Space – Requires space to spread mixed C&amp;D loads in order to pull drywall.</td>
</tr>
<tr>
<td></td>
<td>▪ Contamination – Potential for drywall to become contaminated when mixed with other C&amp;D debris.</td>
</tr>
</tbody>
</table>

4.2.2.3 Results of Disposal Site Separation Program

After several months of implementation of the source separation program, with mixed results, the disposal site separation program was initiated. Disposal site separation was launched at both the Orange County Landfill and the Republic 545 Landfill.

Orange County Landfill

The Orange County Landfill complex includes a Class I cell (for municipal solid waste), a Class III cell (for non-putrescible waste), a residential recycling facility and a household hazardous waste facility. As an integrated solid waste management facility, the Orange County Landfill recycles approximately 114,000 tons of various materials including tires, white goods, metals, glass, paper, cardboard, plastics, yard waste and wood.

The County elected to perform a majority of the disposal site separation at the Landfill’s Class III site where mixed loads of Class III material are regularly delivered. Here, large pieces of drywall were pulled out from the loads that were less than 75% drywall. The County hired several light industrial temporary laborers to manually pick through the piles to positively sort the drywall. Once separated, the pieces of drywall were loaded manually into a roll-off container. The container was emptied at the yard waste pad. Loads that were 75% or more drywall were also tipped at the yard waste pad. These loads were spread using a loader, such that the reject material could be easily removed from the pile. Temporary laborers were again used for this separation process (see Figure 4-1).
From September 2002 through March 2003, approximately 279 tons of drywall were extracted or collected for recycling. In a forty-hour workweek, two temporary laborers could separate approximately 75 cubic yards (or approximately 21 tons) of drywall. The costs associated with the manual separation of drywall are summarized in Section 6 of this report.

Republic 545 Landfill

Recycling has been a core component of the Republic 545 Landfill’s operations since its inception. During calendar year 2000, the 545 Landfill recycled over 43,300 tons of concrete, wood, metals, and land clearing debris (or 11 percent of the total amount of C&D entering the Landfill).

In initiating drywall separation, the 545 Landfill began targeting loads of concentrated drywall (i.e. those loads that were 70 to 80 percent drywall). Separation is performed mechanically utilizing a skid steer loader with a grapple attachment (see Figure 4-2). The skid steer loader is utilized to negatively sort contaminants from the drywall pile. On average, it takes approximately 30 minutes to remove contaminants from a 20 cubic yard load of C&D containing 70 to 80 percent drywall.
Since the inception of the program in August of 2002, the 545 Landfill has segregated more than 115 tons of drywall from mixed C&D loads. Most of this material was processed at the 545 Landfill, but some was taken to the Orange County Landfill for processing demonstrations. During the project, the 545 Landfill separated an average of 14.38 tons per month. The 545 Landfill estimates that, after streamlining and improving the separation process, they could potentially separate approximately 225 cubic yards (or approximately 63 tons) per week. The costs associated with the mechanical separation process utilized by the 545 Landfill are summarized in Section 6 of this report.
One of the most important aspects of investigating the recyclability of a commodity is the availability of markets. Determining the potential end markets for a recycled material should be a first step in assessing a recycling program’s feasibility. Once the end markets have been determined, it is important to know end market specifications so that processing alternatives can be assessed. This section of the report will discuss the processing and marketing of drywall that was collected as part of the project collection efforts discussed in Section 4.

5.1 Processing

5.1.1 Existing Technologies

There are a number of technologies that have been utilized within Florida and throughout the nation to process drywall into a saleable feedstock. These technologies include trommel screens, horizontal grinders, tub grinders, hammer mills, and various other types of equipment. For the purpose of this project, both the Orange County Landfill and the 545 Landfill elected to utilize a trommel screen for processing. A trommel screen was utilized because: 1) Trommel screens had proven to be an effective processing technology during the prior FDEP Innovative Drywall Grants that were conducted since they reduce the size of the material and remove almost all of the paper contamination. 2) The first processing event used a trommel screen that produced material acceptable to the end markets. The University of Florida report includes a more detailed summary of the various technologies available to process drywall as well as a description of companies across the country that have expertise in drywall recycling (See Appendix A).

5.1.2 Mechanics of Trommel Screen

The principle parts of a trommel screen include: 1) a hopper at the front-end of the machine to load the drywall, 2) a rotating drum on the order of 20 to 25 feet long, and 3) two belts that transport the larger material that does not fit through the screen, or the “overs,” and the smaller material that goes through the screen, or the “unders,” to their respective piles. Drywall is fed into the front of the machine using a ramp and loader. The tilt of the trommel screen forces the drywall to move through the trommel screen while the material is tumbled (see Figure 5-1a). During this tumbling process, most of the drywall is separated from its paper backing due to breakage caused by gravity. The smaller pieces of the gypsum core fall through the screen (typically ½ to 1 inch) and onto a conveyor belt where they are conveyed to a pile, roll-off box, etc. (see Figure 5-1b and 5-1d). The “overs” that are too large to pass through the screen.
continue through the trommel screen and out the end where they fall onto another conveyor belt for conveyance to another pile, roll-off container, etc. (see Figure 5-1c). Typically, the “overs” pile contains largely paper as well as some of gypsum that is still attached to the paper. To the extent the “overs” pile contains substantial quantities of gypsum, the pile can be run back through the trommel to achieve higher yields of gypsum. There are three important factors that impact the characteristics of the end product when utilizing a trommel screen for processing. A brief explanation of each is included below.

**Screen size:** The screen size impacts the size of the particles that are capable of traveling through the screen into the “unders” fraction. The screen size selected largely depends upon the market for the processed gypsum. A smaller screen size (on the order of ¼” to ½”) would be utilized for agricultural applications, while a ¾” to 1” screen would be optimal for marketing to the cement industry.

**Speed of the drum:** The drum speed (typically measured in revolutions per minute) impacts the duration during which the drywall is in the drum as well as how vigorous the tumbling action is within the drum. The slower the speed, the longer the drywall is in the drum and the better the separation between paper and gypsum.

**Tilt of the trommel screen:** The tilt of the trommel screen impacts the speed with which the drywall will travel through the drum. The smaller the angle of the trommel, the longer the drywall stays in the drum and the better the separation. A steeper angle will result in faster processing rates but poorer separation of paper and gypsum.
5.1.3 Summary of Processing Events

A total of four processing events were held over the duration of the project. Two of the processing events were held at the Orange County Landfill with another two processing events held at the 545 Landfill. Table 5-1 provides a summary of key statistics for each of the processing events.
Table 5-1
Processing Event Summary

<table>
<thead>
<tr>
<th>Processing Event Location</th>
<th>Date</th>
<th>Unprocessed Tons</th>
<th>Processed Tons</th>
<th>Gypsum</th>
<th>Paper</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Tons</td>
<td>%</td>
<td>Tons</td>
<td>%</td>
</tr>
<tr>
<td>Orange County Landfill</td>
<td>August 15, 2002</td>
<td>84</td>
<td>30</td>
<td>36</td>
<td>54*</td>
</tr>
<tr>
<td>545 Landfill</td>
<td>November 19, 2002</td>
<td>33</td>
<td>24</td>
<td>73</td>
<td>9</td>
</tr>
<tr>
<td>Orange County Landfill</td>
<td>January 30, 2003</td>
<td>306</td>
<td>218</td>
<td>71</td>
<td>88</td>
</tr>
<tr>
<td>545 Landfill</td>
<td>March 13, 2003</td>
<td>42</td>
<td>30</td>
<td>71</td>
<td>12</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>465</td>
<td>302</td>
<td>65</td>
<td>163</td>
</tr>
</tbody>
</table>

*Includes reject material and larger pieces of gypsum that were screened out.

5.1.4 Pre-Processing

Prior to loading the scrap drywall into the trommel screen, the drywall was pre-processed. Pre-processing simply involved running over and tossing the drywall pile with a front-end loader in order to break the larger sheets into smaller fractions (see Figure 5-2). Pre-processing drywall allows for better separation of the paper backing from the gypsum during processing in the trommel screen by breaking the drywall into smaller pieces.

Figure 5-2
Pre-Processing Performed by a Front-end Loader
5.1.5 Processing Equipment

Three different trommel screens were utilized to process drywall during the four processing events held for this project. Table 5-2 below provides a summary of key information on each of these machines. Figure 5-3 depicts all of the trommel screens used in this project for processing.

Table 5-2
Trommel Screens used for Drywall Processing

<table>
<thead>
<tr>
<th>Processing Event Date</th>
<th>Manufacturer/Model</th>
<th>Age</th>
<th>Screen Size</th>
<th>Approximate Processing Speed</th>
<th>Length of Screen</th>
<th>Diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>8/15/02</td>
<td>Retech 720</td>
<td>10 years</td>
<td>¾”</td>
<td>Adjusted</td>
<td>20 feet</td>
<td>6 feet</td>
</tr>
<tr>
<td>11/19/02 &amp; 3/13/03</td>
<td>Retech 723A</td>
<td>10 years</td>
<td>½”</td>
<td>15 RPM</td>
<td>22.5 feet</td>
<td>7 feet</td>
</tr>
<tr>
<td>1/30/03</td>
<td>Powerscreen Trommel 725</td>
<td>New</td>
<td>¾”</td>
<td>Adjusted</td>
<td>21 feet</td>
<td>5 feet</td>
</tr>
</tbody>
</table>

Figure 5-3
(a) Trommel screen at Orange County Landfill used on August 15, 2002;
(b) Trommel screen at 545 Landfill used on November 19, 2002 and March 13, 2003;
(c) Trommel screen at Orange County Landfill used on January 30, 2003.
During the first processing event, an older trommel screen owned by Orange County was utilized for processing. The 545 Landfill utilized its own trommel for both the second and fourth processing events. For the third processing event, the County utilized a newer trommel screen that it had leased.

Three different trommel screens were used and, while there were subtle differences in the speed of processing, separation rates, and overall material quality, all of the machines utilized were similarly effective to one another. The first trommel screen used, however, had two output conveyors (instead of just one) and some larger pieces of gypsum were lost this way. All of the other trommel screens used worked similarly well. This fact speaks to the transferability of drywall processing technology to virtually any community or private sector landfill operator that has access to a trommel screen.

5.2 Markets

Recycled drywall can be utilized as an alternative to mined or synthetic gypsum in a number of applications. This project focused on recycling drywall into three markets: agriculture, cement, and new drywall. For more detailed discussion on the markets for recycled drywall, see Appendix A. Table 5-3 summarizes the specifications, contamination tolerance, and capacity of the end markets.

5.2.1 Agriculture

Many different farms use gypsum as a soil amendment for their crops. Gypsum, which consists of calcium and sulfate, acts as a calcium supplement for many crops. In addition, it can be used to decrease the acidity of soils. There are many different crops that benefit from the addition of gypsum to the soil. In addition, this market does not require any paper separation from the gypsum material because the paper will naturally break down in the soil. All of the material from the November 19, 2002 processing event was used in agriculture. NutriSource, a farming supplies broker in Windermere, Florida, took all of the material for use on citrus and tomato crops. Comments from those that used the material were that the material was satisfactory, but too large in physical shape. The material was ¾”-, when the farmers prefer ¼”-. The larger sizes destroy the vegetation when spread, as the gypsum is shot out from the spreader. In addition to recycling the gypsum material from the November 19th processing event, the paper removed during processing was taken to a worm farm to be recycled.

5.2.2 Portland Cement

Gypsum is used as an ingredient in portland cement to help control the setting time of the cement. Generally, five to ten percent of cement consists of gypsum. Recycled gypsum, such as the gypsum core from drywall, can be used as a substitute for the raw, mined gypsum. Florida Crushed Stone, a cement manufacturer in Brooksville, Florida, took all of the processed material produced at the January 30, 2003 processing event to test in their manufacturing process. The material was found to be satisfactory
in this capacity. See Appendix B for the results of the chemical test on the cement manufactured with recycled gypsum.

### 5.2.3 New Drywall

Gypsum from waste drywall can be recycled back into new drywall. Due to large quantities of scrap from the manufacturing process, drywall typically contains 10-20% recycled material. This market tolerates the least amount of paper or other contamination. Testing of the processed material by U.S. Gypsum, a drywall manufacturing company, from the March 13, 2003 processing event was still on-going at the time this report was written.

<table>
<thead>
<tr>
<th>Market</th>
<th>Specifications</th>
<th>Contamination Tolerance</th>
<th>Potential Market Capacity in Florida (tons per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>Material size must be ¼&quot;, but paper does not need to be removed.</td>
<td>High</td>
<td>93,000</td>
</tr>
<tr>
<td>Portland Cement</td>
<td>Material can be of any size, but must not be wet.</td>
<td>Moderate</td>
<td>256,000</td>
</tr>
<tr>
<td>Drywall</td>
<td>Material size is preferred to be ½&quot;.</td>
<td>Very Low</td>
<td>290,000</td>
</tr>
</tbody>
</table>

[1] Source: University of Florida
There are a number of stakeholders in the recycled drywall “value chain” as well as a multitude of factors that affect the economics of drywall recycling. In order for drywall recycling to be sustainable, the long term economics must be favorable for every party in the value chain. Figure 6-1 below provides a summary of the gypsum drywall recycling value chain.

Figure 6-1
Value Chain of Gypsum and Drywall

- Gypsum is mined in Spain, Canada, or the U.S.
- Gypsum is used in the cement manufacture or as an agricultural supplement.
- Gypsum is used to manufacture drywall.
- Waste drywall is processed to remove the gypsum from the paper.
- Drywall is used in the construction of a house or building. During construction, some drywall is scrapped.
- Drywall is transported away from the job site by a waste hauler.
- Drywall is disposed at a landfill.
- Flow of drywall/gypsum without a recycling system.
- Flow of drywall/gypsum after a recycling system is put in place.
- Flow of drywall/gypsum before and after a recycling system is put in place.
Stakeholders in the value chain include general contractors, drywall contractors, waste hauling companies, landfill operators, and end markets of the recycled drywall. Market factors that impact the economic sustainability of drywall recycling on each of these stakeholders include C&D tipping fees, proximity to end markets, availability and cost of mined or synthetic gypsum, availability of existing processing equipment, availability of low cost disposal for the paper by-product, and numerous other factors.

The remainder of Section 6 will analyze the primary factors that impact the economic feasibility of drywall recycling as well as present a high-level proforma based on the costs and revenues experienced during the project.

6.1 Primary Factors Impacting the Economic Sustainability of Drywall Recycling

While there are a multitude of factors that impact long-term sustainability, there are three factors in particular that truly drive the economic viability of drywall recycling: tipping fees, transportation costs, and cost of virgin material.

6.1.1 Low C&D Disposal Tipping Fees

For most any type of waste stream (including MSW, C&D, vegetative waste, etc.), the most significant barrier to recycling is low disposal tipping fees. This is particularly true within many parts of the State of Florida, where the average C&D disposal tipping fee is approximately $15 to $20 per ton. Disposal sites compete for customers through low disposal fees and convenient locations. With low tipping fees, the cost to dispose is usually less than the cost to recycle depending on hauling distance and any surcharge for contamination. This cost differential creates a significant disincentive to recycling.

6.1.2 Transportation Costs

Costs in hauling material are proportional to the distance that they must be hauled. As the distance that the material must be hauled increases, the costs to haul the material will also increase. Thus, if the recycling facility is too far, the material will not be recycled. Similarly, if the distance to the end market is too great, recycling becomes infeasible. Finally, using a separate container for drywall recycling increases costs by doubling container rental and transport costs.
6.1.3 Low Cost of Virgin Rock and Synthetic Gypsum

Another major factor that impacts the economics of drywall recycling is the market value of competing feedstocks such as virgin rock gypsum and synthetic gypsum. The market value of these competing feedstocks typically serve as the upper bound for the price of a recycled feedstock. The cost of virgin rock gypsum delivered to the Brooksville, Florida area (the location of two large Portland cement plants in Florida) is approximately $14 to $20 per ton. Similarly, the cost of synthetic gypsum is approximately $(-5) to $15 per ton delivered to these same plants. As shown, because both virgin rock gypsum and synthetic gypsum are relatively inexpensive raw materials, little margin is left to collect, process, and transport recycled drywall to end-users without exceeding the cost of these other preferred feedstocks.

6.2 Economic Analysis

As discussed in Section 4, Orange County implemented both a source-separated and disposal-facility-based recycling program for drywall. Due to low participation rates in the source separation program, the vast majority of the drywall collected at the Orange County Landfill, as well as the S45 Landfill, was generated by segregating the drywall from mixed loads at the disposal sites.

The purpose of this section of the report is to present an economic analysis of the costs and revenues to a disposal facility associated with establishing a drywall recycling program. As such, the cost of collection is not considered in this analysis. It should be recognized that the costs and revenues presented in the analysis below will vary depending upon distance to end-markets and other regional factors.

6.2.1 Separation and Processing Costs

The costs to a disposal facility associated with drywall recycling include those for separating the drywall from other mixed C&D debris, processing the drywall to remove paper and other contaminants, and disposing the “overs.” Figure 6-2 depicts processing cost formulas that might be typical for a disposal facility in an urban area. These costs can vary, however, depending on how the drywall recycling operation is set up and other factors. Because drywall recycling for a disposal facility would likely be a batch process rather than continuous process, the optimal situation is if drywall were one of many materials (such as wood waste) being recycled. As such, the capital cost of a trommel screen would be spread across a greater number of tons – thereby lowering the processing costs assigned to drywall.
In Figure 6-2, both the manual and mechanical separation costs are determined using a percent recovery factor. This number represents the amount of processed saleable gypsum material generated from the pre-processed drywall. Thus, if the landfill processes 100 tons of drywall, they will generate 71.36 tons of processed gypsum and 28.64 tons of “overs.” The percent recovery was determined using data from only the
last three processing events. Data from the first processing event was excluded because of the losses that occurred from using a trommel screen with three conveyor belts (as opposed to two) at that event.

6.2.2 Revenues

Revenues include the sale of the end product (processed gypsum) as well as the tipping fee charged for accepting the scrap drywall. The tipping fee can be lowered to try to encourage haulers and contractors to separate their drywall from the rest of the mixed C&D debris at the job site.

6.2.3 Economic Scenarios of Drywall Recycling to a Disposal Facility

The following analysis was performed based on the data collected during drywall recycling operations at the Orange County Landfill and the 545 Landfill. While the analysis presented below is specifically for these two facilities, virtually any other facility could be substituted as long as the tipping fee is changed accordingly. In addition, other changes, such as equipment costs, would have to be made to tailor this analysis to a specific facility. Tables 6-1 and 6-2 investigate the net profit or loss when the drywall is separated at the disposal site. Tables 6-3 and 6-4 investigate the total profit or loss from accepting only segregated material and charging a discounted tipping fee or no tipping fee at all. In reality, some mixture of two or more of these systems would have to be implemented in order to break even.

Table 6-1

<table>
<thead>
<tr>
<th>Activity</th>
<th>Orange County</th>
<th>545 Landfill</th>
</tr>
</thead>
<tbody>
<tr>
<td>Separation</td>
<td>($49.19)</td>
<td>($49.19)</td>
</tr>
<tr>
<td>Processing</td>
<td>($5.23)</td>
<td>($5.23)</td>
</tr>
<tr>
<td>Paper/&quot;Overs&quot; Disposal</td>
<td>($4.93)</td>
<td>($5.41)</td>
</tr>
<tr>
<td><strong>Total Costs</strong></td>
<td>($59.35)</td>
<td>($59.83)</td>
</tr>
<tr>
<td>Tipping Fee</td>
<td>$17.20</td>
<td>$18.88</td>
</tr>
<tr>
<td>Sale of material*</td>
<td>$5.00</td>
<td>$5.00</td>
</tr>
<tr>
<td><strong>Total Revenue</strong></td>
<td>$22.20</td>
<td>$23.88</td>
</tr>
<tr>
<td><strong>Net Profits/(Losses)</strong></td>
<td>($37.15)</td>
<td>($35.95)</td>
</tr>
</tbody>
</table>

*Does not include transportation costs to the end market.
Table 6-2
Economics of Non-Segregated Collection and Mechanical Separation
Costs/Revenues per Processed Ton

<table>
<thead>
<tr>
<th>Activity</th>
<th>Orange County</th>
<th>545 Landfill</th>
</tr>
</thead>
<tbody>
<tr>
<td>Separation</td>
<td>$ (15.93)</td>
<td>$ (15.93)</td>
</tr>
<tr>
<td>Processing</td>
<td>$ (5.23)</td>
<td>$ (5.23)</td>
</tr>
<tr>
<td>Paper/&quot;Overs&quot; Disposal</td>
<td>$ (4.93)</td>
<td>$ (5.41)</td>
</tr>
<tr>
<td><strong>Total Costs</strong></td>
<td>$ (26.09)</td>
<td>$ (26.57)</td>
</tr>
<tr>
<td>Tipping Fee</td>
<td>$ 17.20</td>
<td>$ 18.88</td>
</tr>
<tr>
<td>Sale of material [1]</td>
<td>$ 5.00</td>
<td>$ 5.00</td>
</tr>
<tr>
<td><strong>Total Revenue</strong></td>
<td>$ 22.20</td>
<td>$ 23.88</td>
</tr>
<tr>
<td><strong>Net Profits/(Losses)</strong></td>
<td>$ (3.89)</td>
<td>$ (2.69)</td>
</tr>
</tbody>
</table>

[1] Does not include transportation costs to the end market.

Table 6-3
Economics of Segregated Collection and 50% Discounted Tipping Fee
Costs/Revenues per Processed Ton

<table>
<thead>
<tr>
<th>Activity</th>
<th>Orange County</th>
<th>545 Landfill</th>
</tr>
</thead>
<tbody>
<tr>
<td>Separation</td>
<td>$ -</td>
<td>$ -</td>
</tr>
<tr>
<td>Processing</td>
<td>$ (5.23)</td>
<td>$ (5.23)</td>
</tr>
<tr>
<td>Paper/&quot;Overs&quot; Disposal</td>
<td>$ (4.93)</td>
<td>$ (5.41)</td>
</tr>
<tr>
<td><strong>Total Costs</strong></td>
<td>$ (10.16)</td>
<td>$ (10.64)</td>
</tr>
<tr>
<td>Tipping Fee</td>
<td>$ 8.60</td>
<td>$ 9.44</td>
</tr>
<tr>
<td>Sale of material [1]</td>
<td>$ 5.00</td>
<td>$ 5.00</td>
</tr>
<tr>
<td><strong>Total Revenue</strong></td>
<td>$ 13.60</td>
<td>$ 14.44</td>
</tr>
<tr>
<td><strong>Net Profits/(Losses)</strong></td>
<td>$ 3.44</td>
<td>$ 3.80</td>
</tr>
</tbody>
</table>

[1] Does not include transportation costs to the end market.
As seen in Tables 6-1 through 6-4, there are a number of scenarios that can be run to evaluate the cost effectiveness of drywall recycling to a disposal facility. Clearly, due to the high cost of separating drywall from mixed loads, those programs that utilize source-separated collection are far more economically viable than those programs that source drywall from mixed C&D loads.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Orange County</th>
<th>545 Landfill</th>
</tr>
</thead>
<tbody>
<tr>
<td>Separation</td>
<td>$ -</td>
<td>$ -</td>
</tr>
<tr>
<td>Processing</td>
<td>$ (5.23)</td>
<td>$ (5.23)</td>
</tr>
<tr>
<td>Paper/”Overs” Disposal</td>
<td>$ (4.93)</td>
<td>$ (5.41)</td>
</tr>
<tr>
<td><strong>Total Costs</strong></td>
<td>$ (10.16)</td>
<td>$ (10.64)</td>
</tr>
<tr>
<td>Tipping Fee</td>
<td>$ -</td>
<td>$ -</td>
</tr>
<tr>
<td>Sale of material [1]</td>
<td>$ 5.00</td>
<td>$ 5.00</td>
</tr>
<tr>
<td><strong>Total Revenue</strong></td>
<td>$ 5.00</td>
<td>$ 5.00</td>
</tr>
</tbody>
</table>

**Net Profits/(Losses)**

<table>
<thead>
<tr>
<th></th>
<th>Orange County</th>
<th>545 Landfill</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$ (5.16)</td>
<td>$ (5.64)</td>
</tr>
</tbody>
</table>

[1] Does not include transportation costs to the end market.
The purpose of Section 7 of this report is to address the specific reporting requirements of the FDEP for Innovative Recycling Grants. In accordance with FDEP guidelines, this report has been divided into the following three sections:

- Section A - Introduction to the Project;
- Section B - Project Implementation; and
- Section C - Project Results.

**Section A – Introduction to the Project**

**A.1 - Background**

Construction and demolition (C&D) waste results from the construction, demolition and renovation of buildings, bridges, roads and other structures. Gypsum drywall represents one of the more common components of the C&D waste stream along with concrete, asphalt, wood, metal, cardboard, plastic, and soil. As Florida's population grows and C&D related activity continues at a rapid pace, large amounts of C&D waste are generated. According to the Florida Department of Environmental Protection (FDEP), construction and demolition waste accounted for approximately 20 percent of the municipal solid waste (MSW) stream in Florida in 1999. The large contribution of C&D waste to the overall waste stream, combined with possible environmental impacts when disposed and a relatively low recycling rate, have placed renewed attention on this often overlooked material.

Gypsum drywall stands out as one component of C&D waste that warrants additional attention. It represents the largest material found in C&D waste that currently does not have an established market in Florida. Concrete and wood are certainly larger components of the C&D waste stream, but markets for recycled concrete and wood do exist. Successful gypsum drywall recycling programs operate in other areas of North America. Gypsum drywall also merits special attention because of its possible impact on the environment during disposal. When disposed in a landfill, conditions often develop that result in the biological transformation of gypsum to hydrogen sulfide, a foul-smelling gas that is toxic at high concentrations. Many C&D waste landfills suffer from this problem. One factor limiting landfill operators from minimizing the amount of drywall that is disposed is the lack of available recycling markets.

In March 2000, Orange County was awarded an Innovative Recycling Grant by FDEP for the purpose of implementing a drywall recycling program. Orange County was designated as the lead county, with Seminole County serving as a partner county.
A.2 Project Objectives
The principal objective of this project was to continue the collection and dissemination of data on drywall recycling technologies and opportunities. Prior drywall recycling efforts within the State of Florida were conducted in rural areas and proved economically unsustainable, largely because these areas did not generate enough raw material to develop programs with economies of scale.

A.3 Innovative Nature of the Project
This Orange/Seminole Grant project was innovative in two ways. First, the targeted material for recycling was gypsum drywall. Only a few pilot recycling programs have ever been attempted targeting gypsum drywall. Second, unlike previous drywall recycling efforts in Florida (which were conducted during the 1998-1999 FDEP Grant Cycle), this drywall recycling program was the first in the state to be conducted in a largely urban area. One of the primary barriers identified in the previous pilot programs was generating sufficient quantities of drywall to make the program economically feasible.

A.4 Project Presentation and Articles
Included in Table 7-1 is a summary of the project presentations and articles delivered by the Project Team in presenting the results of this project. Copies of articles are included in Appendix C.
Table 7-1

Project Presentations and Articles

<table>
<thead>
<tr>
<th>Conference/Meeting/Publication Name</th>
<th>Location</th>
<th>Date</th>
<th>Presenter/Author</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Presentations</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TAG Meeting</td>
<td>Orlando, FL</td>
<td>11/8/01</td>
<td>Tom Edwards, Tim Townsend</td>
</tr>
<tr>
<td>FDEP Central District Solid Waste</td>
<td>Kissimmee, FL</td>
<td>11/13/02</td>
<td>Kim Cochran</td>
</tr>
<tr>
<td>Directors Meeting</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TAG Meeting/Processing Event</td>
<td>Orlando, FL</td>
<td>11/19/02</td>
<td>Chuck McLendon, Kim Cochran</td>
</tr>
<tr>
<td>TAG Meeting/Processing Event</td>
<td>Orlando, FL</td>
<td>1/30/03</td>
<td>Kim Cochran, Tim Townsend, Chuck McLendon</td>
</tr>
<tr>
<td>SWANA Annual Collection and Recycling Symposium</td>
<td>Orlando, FL</td>
<td>2/25/03</td>
<td>Kim Cochran</td>
</tr>
<tr>
<td>TAG Meeting/Processing Event</td>
<td>Orlando, FL</td>
<td>3/13/03</td>
<td>Kim Cochran, Chuck McLendon</td>
</tr>
<tr>
<td><strong>Articles and News Releases</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yahoo! Finance Website</td>
<td>N/A</td>
<td>1/6/03</td>
<td>Project Team</td>
</tr>
<tr>
<td>PR Newswire Website</td>
<td>N/A</td>
<td>1/6/03</td>
<td>Project Team</td>
</tr>
<tr>
<td>News Alert Website</td>
<td>N/A</td>
<td>1/6/03</td>
<td>Project Team</td>
</tr>
<tr>
<td>Finance Canada.com</td>
<td>N/A</td>
<td>1/6/03</td>
<td>Project Team</td>
</tr>
<tr>
<td>CBS MarketWatch.com</td>
<td>N/A</td>
<td>1/6/03</td>
<td>Project Team</td>
</tr>
<tr>
<td>CDRrecycler.com</td>
<td>Cleveland, OH</td>
<td>1/6/03</td>
<td>Dan Soltis</td>
</tr>
<tr>
<td>Public Works</td>
<td>Ridgewood, NJ</td>
<td>March 2003</td>
<td>Project Team</td>
</tr>
<tr>
<td>Orlando Business Journal</td>
<td>Orlando, FL</td>
<td>3/13/03</td>
<td>Project Team</td>
</tr>
<tr>
<td>The Florida Specifier</td>
<td>Winter Park, FL</td>
<td>March 2003</td>
<td>Prakash Gandhi</td>
</tr>
<tr>
<td>P M Network</td>
<td>Newtown Square, PA</td>
<td>April 2003</td>
<td>Project Team</td>
</tr>
</tbody>
</table>

**Section B – Project Implementation**

**B.1 Equipment/Services Purchased**

Table 7-2 provides a summary of the various services and equipment purchased as part of this grant project as well as how the service/equipment was utilized.
Table 7-2  
Services Rendered and Equipment Purchased

<table>
<thead>
<tr>
<th>Equipment/Service</th>
<th>Provider Name</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineering Consultant</td>
<td>SCS Engineers/R.W. Beck</td>
<td>Project management, Collection logistics, Promotion, Communication</td>
</tr>
<tr>
<td>Processing Services</td>
<td>Agricycle, Ltd.</td>
<td>Drywall processing</td>
</tr>
<tr>
<td>Bobcat Equipment Lease</td>
<td>Republic 545 Landfill</td>
<td>Separation of drywall from commingled C&amp;D loads</td>
</tr>
<tr>
<td>Roll-Off Containers</td>
<td>Hesco Sales, Inc.</td>
<td>Collect drywall via County roll-off truck for source separated sites</td>
</tr>
<tr>
<td>Temporary Labor</td>
<td>WorkForce</td>
<td>Separation of drywall from commingled C&amp;D loads</td>
</tr>
</tbody>
</table>

B.2 Cooperative Recycling Effort

This project was a joint effort of Orange and Seminole Counties. Projects such as this are best performed on a regional basis as the various stakeholders (waste haulers, contractors, landfills) involved typically service a broader geographic area rather than a single county.

Orange County targeted collection efforts at the Orange County Landfill and Republic’s 545 Landfill. Seminole County established a separation program at their Central Transfer Station. Project promotion and public education efforts were coordinated and conducted jointly by the two counties.

B.3 Project Elements and Timeline

This project consisted of four primary components. A brief description of each component is included below.

Project Administration/Management: A key ingredient of any successful project is sound project management. Given the number of stakeholders involved in this project, project management was a critical element.

Project Promotion/Stakeholder Involvement: Another key element of this project was obtaining feedback from stakeholders. A total of four Technical Advisory Group meetings, consisting of waste haulers, landfill operators, general contractors, end markets, and other parties, were held in order to exchange ideas and find ways to eliminate barriers. In addition, project promotion, in the form of face-to-face meetings, flyers, press releases, and magazine articles, were performed over the course of the project.

Collection Program: As part of the collection program general contractors and waste haulers were contacted to determine their interest in the program. Containers were delivered and collected at those sites that chose to participate in the source separated
collection program. Orange and Seminole Counties project staff arranged for the collection of material.

**Separation/Processing Program:** Separation and processing were performed at the Orange County Landfill and the Republic 545 Landfill. Orange County utilized manual labor to separate drywall from mixed C&D loads, while the 545 Landfill used skid steers with grapples for separation. Processing at both sites was performed using a trommel screen.

A project timeline which includes a step by step summary of the various project tasks is included as Appendix D.

**B.4 Problems Encountered/Resolutions**

Like any pilot project, there were a number of problems that were encountered over the course of the project. A brief summary of each of the problems encountered and how each problem was resolved is included below.

**Contractor Participation/Drywall Sourcing:** The Project Team’s original plan for sourcing drywall relied largely on source separation. In other words, the drywall contractor would be responsible for placing drywall in a roll-off container designated only for drywall. The general contractors showed little interest because of the short duration of the project and additional container rental and transport costs. Rather than trying to change the existing C&D collection system, the project instead began focusing on separation of mixed loads delivered to the disposal facilities.

**Processing Vendor:** Based on their prior experience in processing scrap drywall for recycling, Orange County retained Agricycle, Ltd. to serve as the County’s drywall processor. Agricycle participated in the first two processing events. Unfortunately, the company exited from the project due to some internal issues at their headquarters in Ohio. Upon Agricycle’s departure from the project, the County and the 545 Landfill assumed responsibility for processing the drywall.

**Section C – Project Results**

**C.1 Satisfaction of Goals/Objectives**

Results indicate that this project has achieved its objective of collecting and disseminating data on drywall recycling technologies and opportunities. Additionally, the Republic/545 Landfill has plans to continue the separation, processing, and marketing of scrap drywall beyond the conclusion of this grant project. A business plan for drywall recycling at the 545 Landfill is included in Appendix E. The plan was prepared by Republic/545 Landfill staff.

**C.2 Advanced Technologies/Processes**

To the Project Team’s knowledge, there are no existing drywall recycling programs in the State of Florida. This project included a total of four drywall processing demonstration trials that were attended by a variety of stakeholders from across the state.
Section 7

Two drywall recyclers, Agri-Cycle and New West Gypsum, with operations outside of Florida were interested in expanding operations to Florida. Agri-Cycle had been contracted to supervise all processing demonstrations performed for this project. However, after two processing demonstrations, financial problems within the company prevented them from continuing to partner in the project. New West Gypsum is still interested in expanding to Florida. They discussed their intentions with the project team in February 2003 and observed a processing demonstration at the 545 Landfill on March 13, 2003. A memorandum from New West Gypsum to Orange County is provided in Appendix F and discusses their comments and thoughts about drywall recycling in Florida.

C. 3 Greater Quantities of Recovered Materials

During the grant period, a total of 465 tons of scrap drywall were collected and recycled. We anticipate that the continued operation of the 545 Landfill collection program will result in approximately 3,300 tons per year of drywall diverted from disposal for recycling, although the drywall waste stream into the 545 Landfill amounts to as much as 58,000 tons per year. More drywall could be recovered if the system at the 545 Landfill were to be made more efficient and effective.

In addition, as a result of end-market participation in the project, we have received feedback on methods to improve the marketability and increase the value of the recycled drywall to their respective industries.

C.4 Transferability

This project has clearly demonstrated that virtually any municipality or private sector landfill operator with the desire to divert drywall and save landfill space can do so. This project has demonstrated that, like many recyclable materials, the primary barriers to establishing effective diversion programs are not technological, but rather economic. The key to overcoming the economic obstacles of drywall recycling is establishing a network of stakeholders along the drywall recycling value chain (including contractors, waste haulers, landfill operators, end markets, etc.) to work collaboratively and understand the barriers that each member of the chain has individually.
C.5 Recycling Cost Effectiveness and Efficiency

C.5.a Expenditures by Component

Table 7-3
Projected Grant Expenditures by Component

<table>
<thead>
<tr>
<th>Project Task</th>
<th>Admin.</th>
<th>Equipment</th>
<th>Operations</th>
<th>Advertising/ Education</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 Vendor Contracts</td>
<td>$12,000</td>
<td></td>
<td>$1,290</td>
<td></td>
<td>$13,290</td>
</tr>
<tr>
<td>2.0 TAG Meetings</td>
<td>$3,000</td>
<td></td>
<td></td>
<td>$3,000</td>
<td>$6,000</td>
</tr>
<tr>
<td>3.0 Promotion and Implementation</td>
<td>$60,000</td>
<td>$12,450</td>
<td></td>
<td>$6,000</td>
<td>$78,450</td>
</tr>
<tr>
<td>4.0 Facility Development and Operation</td>
<td>$12,000</td>
<td>$10,500</td>
<td>$2,878</td>
<td></td>
<td>$25,378</td>
</tr>
<tr>
<td>5.0 Economic Analysis and Outreach</td>
<td>$18,000</td>
<td></td>
<td>$6,794</td>
<td>$5,967</td>
<td>$30,761</td>
</tr>
<tr>
<td>Project Totals</td>
<td>$105,000</td>
<td>$22,950</td>
<td>$10,962</td>
<td>$14,967</td>
<td>$153,879</td>
</tr>
</tbody>
</table>

C.5.b. Public vs. Private and Grant vs. County In-kind Expenditures

Public sector funds were expended by both Orange County and Seminole County. Non-reimbursable private sector funds were expended by the Republic 545 Landfill as well as several private sector waste haulers that delivered segregated drywall for processing. Table 7-4 describes the funds that were expended as part of the grant.

Table 7-4
Funds Expended by Sector

<table>
<thead>
<tr>
<th></th>
<th>Public Sector Funds</th>
<th>Private Sector Funds</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grant Funds</td>
<td>In-Kind Funds</td>
</tr>
<tr>
<td>Orange County</td>
<td>$153,879</td>
<td>$58,397</td>
</tr>
<tr>
<td>Seminole County</td>
<td></td>
<td>$6,832</td>
</tr>
<tr>
<td>545 Landfill</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Private Sector Collection</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total Funds Expended</strong></td>
<td><strong>$153,879</strong></td>
<td><strong>$65,229</strong></td>
</tr>
</tbody>
</table>

[1] Private Sector Collection funds represent funds used to cover all efforts put forth by private C&D debris haulers. Efforts included educating their clients to source separate drywall and divert drywall loads to the Orange County Landfill instead of an alternate landfill.

C.5.c Avoided Tipping Fees

A total of 465 tons of drywall were collected over the course of this project resulting in avoided tipping fees of approximately $8,000.
C.5.d Cost/Benefit Ratio

Avoided Material Tonnage/Space: This recycling program diverted a total of 465 tons, 1,670 loose yards, or 600 compacted yards of drywall from Orange and Seminole County landfills.

Conservation of Natural Resources: While extremely plentiful, gypsum is an important natural resource. Drywall recycling has the potential to conserve tens of thousands of tons of raw gypsum each year in the State of Florida alone.

Costs per Capita/Costs per Ton: The cost per capita of this drywall recycling program was $0.12 per resident ($153,879/1,307,994 persons) of Orange and Seminole Counties. The cost per ton for the grant program was $330.92 per ton diverted ($153,879/465 tons).

C.6 Collection/Recycling of Non-Traditional Materials

This project targeted drywall for recycling. To our knowledge, there are not any existing drywall recycling programs in the state. As a result of this project, a number of key stakeholders that must be involved in drywall recycling within the state of Florida, were brought together to develop a better understanding on how to make drywall recycling economically sustainable within the state of Florida.

We were able to show representatives from a number of end-markets that gypsum sourced from recycled drywall is a viable feedstock for their processes. Most importantly, as a result of this project, it appears that the state has its first sustainable drywall recycling program.
MARKETS FOR GYPSUM

For gypsum drywall recycling to be successful, it is essential to have a reliable end-user market. Virgin gypsum is cheap and abundant, so there must be a competitive price or an economic benefit for recycled material to be used in its place. The economic viability of drywall recycling depends on factors such as collection, processing, transportation, landfill tipping fees and the value that end-user markets place on recycled gypsum products. Several end-user markets are identified in Table 3-1 and further explored in this chapter.

Table 3-1. Potential markets for recovered gypsum drywall

<table>
<thead>
<tr>
<th>Market</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacture</td>
<td>New drywall</td>
</tr>
<tr>
<td></td>
<td>Portland cement</td>
</tr>
<tr>
<td></td>
<td>Flea powder</td>
</tr>
<tr>
<td>Agriculture</td>
<td>Plant nutrient</td>
</tr>
<tr>
<td></td>
<td>Improving soil structure</td>
</tr>
<tr>
<td></td>
<td>Reclamation of sodic soils</td>
</tr>
<tr>
<td></td>
<td>Correction of subsoil acidity</td>
</tr>
<tr>
<td></td>
<td>Animal bedding</td>
</tr>
<tr>
<td></td>
<td>Plant disease prevention</td>
</tr>
<tr>
<td></td>
<td>Reducing phosphorous leaching from manure-loaded soils</td>
</tr>
<tr>
<td></td>
<td>Compost</td>
</tr>
<tr>
<td>Construction</td>
<td>New construction soil amendment</td>
</tr>
<tr>
<td></td>
<td>Road construction</td>
</tr>
<tr>
<td></td>
<td>Construction materials</td>
</tr>
<tr>
<td>Other</td>
<td>Bulking and drying agent</td>
</tr>
<tr>
<td></td>
<td>Settlement of dirt and clay particles in turbid water</td>
</tr>
<tr>
<td></td>
<td>Absorbent for greases</td>
</tr>
</tbody>
</table>
The primary markets for recycled drywall identified in this chapter include agriculture, Portland cement manufacturing, composting, and new drywall. A brief section on other recycling markets is also included. This chapter reviews these markets in detail. Also included in this chapter are sections on processing gypsum drywall waste and other existing recycling programs.

**REUSE OF GYPSUM IN THE MANUFACTURE OF NEW DRYWALL**

Gypsum from waste drywall can be recycled back into new drywall. Many wallboard manufacturers will only use their own off-spec materials because of quality requirements they must adhere to. Paper content also dictates how much recycled material may be used due to concerns about flammable properties of the new wallboard product. Usually, only about 10 to 20% of the new product consists of recycled gypsum. The recycled gypsum is combined with virgin rock and fed into the process. It must contain less than 2% paper and cannot contain any metal fragments such as nails and screws (CWC, 1995). To prepare for reuse, the drywall scraps must go through a process to have the paper backing removed. All of the ferrous pieces are removed from the discarded drywall by a magnet. See Chapter 2 for a description of how drywall is made.

Byproduct gypsum is also used in the manufacture of new drywall. Gypsum by-products are produced from the manufacture of several acid manufacturing industries, such as phosphoric, hydrofluoric, and citric acid. It is also formed from flue gas desulfurization processes, such as those at coal-fired power plants. During the desulfurization process, compressed air is blown into reaction tanks where limestone slurry absorbs SO₂ that is released from burning coal. Synthetic gypsum is produced from this process and can be dehydrated to make new gypsum drywall (Bench Mark, 1999). Byproduct gypsum from flue gas desulfurization is either landfilled on site or sold for the manufacture of new drywall (Wolsiffer and Wedig 1997, Barsotti and Kalyoncu, 1996).

**GYPSUM USE IN THE MANUFACTURE OF PORTLAND CEMENT**

Cement binds sand and gravel together to form concrete. Concrete is the most widely used construction material in the world. It is used to build a large variety of structures and construction products, including dams, bridges, pipes for water, foundations, blocks, and utility poles. Concrete consists of crushed stone, sand, water, cement, and air. The percentages of these ingredients in concrete are illustrated in Figure 3-1.
Recycling of Gypsum Drywall

Any type of cement that hardens under water is known as hydraulic cement. This includes Portland cement, which is the most commonly used type of cement. Portland cement is made from limestone, sand, clay, shale, water, and gypsum. Figure 3-2 describes the chemical composition of cement by volume. All of these components are derived from the limestone, sand, clay, shale, water, and gypsum.
Figure 3-2. Composition of cement by volume (MarketPlace Cement, 2001)

When water is added to cement, it triggers a chemical reaction called hydration. This reaction forms a gel that hardens and binds sand and gravel into a solid mass. Although most of the strength develops in the first few days, the cement can continue to harden for years if moisture is present. The rate of hydration controls the concrete's setting time. Different additives, including gypsum, are used to control the setting time. Different amounts of additives are used, depending on the specific application of the concrete. Gypsum comprises 6% (or 120 lbs.) of every ton of cement produced at Florida Crushed Stone (Wheeler, personal communication, 2000). This percentage may vary elsewhere from 5 to 10%. Temperature affects the setting time, so special considerations are needed if the cement is to be used in the summer versus the winter. Concrete is used in residential and non-residential buildings, highways, streets and bridges, maintenance and repair, water and waste infrastructure, non-construction purposes, and for other applications, as shown in Figure 3-3.
Figure 3-3. Major uses of concrete (Portland Cement Association, 2000)

The process of making cement starts with limestone mining. Limestone is crushed to the size of gravel. After this limestone has been transported to the cement plant from the quarry, it is crushed into a powder and blended with other minerals, such as sand, clay, iron ore, or shale. Then cement manufacturers use either a dry or wet process to produce clinker. Most manufacturers use a dry process and the wet process is used mainly by older factories. In the dry process, the powder is placed directly into the preheater. In the wet process, water is first added to form slurry. The raw material, either in the form of a powder or as slurry, is heated up from 20°C to about 900°C in a preheating tower. The preheater tower, more than 200 ft high, is the largest feature on the cement manufacturer’s property. The raw material goes through a series of cyclones on its way to the rotary kiln. Along the way, the water is evaporated and 95% of the calcination occurs. Calcination is the process of driving off carbon dioxide from limestone (calcium carbonate) to form lime (calcium oxide). The lime is then fed into a rotary kiln. This kiln is a horizontally sloped cylinder that turns about one to three revolutions per minute. In this kiln, it is heated from 600°C to about 1450°C. From this extreme heat, it undergoes a chemical reaction to form clinker. In the calcining zone, which heats from 600°C to 900°C,
calcination is completed. The material then goes to the burning zone (Wheeler, personal communication, 2000)

Old rotary kiln (left) and preheater (right) at Florida Crushed Stone, Brooksville, Florida.

In the burning zone, where the kiln is heated from 1200°C to 1450°C, the lime reacts with silica and other materials to form dicalcium silicate, tricalcium aluminate, and tetracalcium aluminoferrite. Tricalcium aluminate and tetracalcium aluminoferrite, when in liquid state, meld solids into clinker. The rest of the lime reacts with the dicalcium silicate and forms tricalcium silicate. The materials are in the hottest zone at the end, at a temperature of 1480°C, and the materials are partially molten. The clinker that is produced is then rapidly cooled by air blown through large fans as it passes over a grate. This hot air is returned to the kiln or preheater in order to save energy. It is ground and a small amount of gypsum is added. Gypsum is added to improve the properties of the concrete and to control the setting of concrete. The mixture is sent to a ball mill and ground to a very fine powder with particles as small as 1/25,000 of an inch. The cement manufacturing process is then complete and it can be either stored in silos or transported in road tankers. Figure 3-3 presents an overview of the dry cement making process (FCS, 2000).

The amount of cement produced in the United States has been constantly changing in the past 30 years. This 28-year trend of production and demand is represented in Figure 3-4. In 1970, the
Demand for cement in the United States was about 69 million metric tons. Of that, 66 million tons was produced in the U.S. In 1998, the demand was about 81 million metric tons, and almost 80 million tons was produced in the U.S. Demand was at a minimum in 1982 at 58.6 million metric tons and peaked in 1987 at 82 million tons. The industry has been trying to keep with this trend, but as shown in figure 3-4, it is not always able to.

Figure 3-3. The dry portland cement making process (FCS, 2000).
There are seven active cement plants in Florida (see Figure 3-5). Tarmac and Rinker are located in Miami. Lafarge Corporation has two plants, one in Palmetto and one in Tampa. Florida Crushed Stone and Southdown are located in Brooksville and Florida Rock Industries is located in Newberry.

In 1998, 9,401,388 tons of C&D waste were collected in the state of Florida and 6,112,923 million tons, or 65%, were disposed. That same year, 1,881,566 tons of concrete were recycled. That amounts to 20% of all C&D waste that was collected. Concrete is the most recycled C&D product, comprising 57% of the total amount of C&D material that is recycled (FDEP H, 1999).
GYPSUM USE IN AGRICULTURE

The primary potential uses for gypsum in agriculture are

- As a source of plant nutrients
- Improving soil structure
- Reclamation of sodic soils
- Correction of subsoil acidity

Mined or by-product gypsum may be used in agriculture. Mined gypsum, also referred to as raw or virgin gypsum, has been used in agriculture for over 200 years for supplying calcium and sulfur to soils. By-product gypsum is produced during the manufacture of phosphoric, hydrofluoric, or citric acid manufacturing. The gypsum by-products are also produced by the pollution control systems, such as flue gas desulfurization at coal-fired power plants. Since the by-product gypsum is often produced in reasonably pure form, typically greater than 90%, it would be suitable for use as a soil amendment or in the manufacture of new gypsum drywall. However, land application of by-product gypsum
Appendix A

has raised environmental concerns because of the presence of trace amounts of impurities from the neutralization of waste acids.

There are currently no prescribed formulas for calculating scrap gypsum application rates for soils. Ranges of application have fallen between one-half (Breman, 2000) and 22 tons per acre (Burger, 1993). Ritchey et al. (1995) notes that chemical, mineralogical, climatic and physical factors should be included when determining such a number, and further concluded that there was no current method for determining application rates of gypsum for agricultural benefits.

Benefits of Gypsum in Agriculture

Gypsum is inexpensive and easily obtainable, making it the most widely used soil amendment for reclamation (Shainberg et al., 1989). Reclamation or amelioration refers to the exchange of calcium for sodium in sodic soils. Sodic or saline soils are those that contain soluble salts and exchangeable sodium at levels that interfere with the growth of most crops. Gypsum has also been used as a soil amendment because of its beneficial effect on the physical and chemical properties of soil. It can improve filtration, increase rooting in acid subsoils and supply calcium and sulfur to plants (Korcak, 1996). In addition to being used as a soil amendment, gypsum has also been studied to determine its effects on crop production and yield. Gypsum has been applied to a variety of crops, such as peanuts (Alva et al., 1989), brussels sprouts (Carter and Cutliffe, 1990), soybeans (Alva and Sumner, 1989), corn (Burger, 1993) and cotton (Caldwell et al., 1990). A comprehensive list of gypsum’s benefits in agriculture are outlined by Wallace (1994). The following subsections will detail the benefits of using gypsum in agriculture.

A biological “quick” test to identify soil situations where gypsum application would be beneficial was developed to identify soil calcium deficiency and/or aluminum toxicity (Ritchey et al., 1989). The test compares root lengths of 4-day seedling growth in a soil alone or amended with limestone as a calcium source. Growth of 30% or more shows that a beneficial result could occur from treatment and 15% or less growth shows that limited benefit could be expected from treatment. This method is good because it is simple and does not require analysis by an analytical laboratory. This test was not performed using scrap gypsum drywall.

Gypsum as a Plant Nutrient

Gypsum is calcium sulfate dihydrate (CaSO₄•2H₂O). Since calcium and sulfur are among the 16 essential plant nutrients, experiments have been conducted based on the hypothesis that clean gypsum drywall waste would be beneficial to crops as a source of both calcium and sulfur where needed. Calcium is needed for cell wall strength and enzyme activity in plants and sulfur is used to build proteins. Certain crops
require more calcium and sulfur than others and these are presented in the following paragraphs.

Vegetables such as tomatoes, peppers, watermelon, escarole lettuce, celery, cauliflower and cabbage all require calcium or they will show deficiencies. Calcium plays a role in the development of cells of plants, keeps cell membranes intact and hormones functioning properly, helps to deter the toxic effects of aluminum. Vegetable crops that have a calcium deficiency can display symptoms such as restricted growth of shoots and roots, blossom end rot of tomatoes, peppers and watermelon, brownheart of escarole, celery blackheart, and cauliflower or cabbage tipburn (Maynard and Hochmuth, 1999). These symptoms usually occur on strongly acidic soils or during severe droughts in Florida. Most crops do not show such severe symptoms, however, the yield could be reduced just because the crop did not grow up to its potential.

The class of vegetables called legumes includes: beans, peas, lentils and garbanzo beans, or chickpeas. People have been eating legumes for thousands of years and these foods are the main source of protein for people in many developing countries. Peanuts, which are also legumes, require a great deal of calcium to ensure proper growth. Even a slight deficiency can prevent correct pod formation, creating a significant loss in yield. According to the Institute of Food and Agricultural Sciences (IFAS) at the University of Florida, peanuts need calcium to ensure proper growth and prevent certain plant diseases (IFAS, 2000).

Gypsum is typically used to supply the calcium to peanuts for effective fruit development (Harun, 1985). Gypsum insures pod growth, reduces pod rot caused by imbalances of other nutrients, and improves the viability of peanuts produced for seed. In a study by Harun (1985), it was found that gypsum reduced the damaged kernels percentage and peanut pod rot percentage, significantly increased calcium levels in the fruiting zone, and was more effective in increasing the calcium levels in the fruiting zone during fruit development than lime.

The peanut is the major crop in the southeast for which calcium requirements are most crucial. Gypsum should be applied to peanuts no later than early flowering, which occurs about 30 days after planting.
Gypsum is typically applied at the rate of about 600 - 800 pounds per acre (Breman, personal communication, 2000). The maximum gypsum rate recommended for peanuts in the Southeast is 1720 pounds of gypsum per acre. However, since farmers typically grow peanuts in a three-year crop rotation to increase their profits, this amount decreases to 573 pounds of gypsum per acre on an annual long-term basis. Gypsum is used as the calcium source because it doesn’t raise pH and is highly soluble. Gypsum is a neutral salt, and according to Shainberg et al. (1989) has a solubility of 2.5 g/L or 15 mM. Salts such as calcium carbonate and calcium chloride are either less soluble or more soluble, respectively (Shainberg et al., 1989). Because some soils require different amounts of calcium, proper soil testing can evaluate the recommended levels of gypsum to be applied to a specific type of soil. Application rates of gypsum are based on levels of exchangeable sodium present in the soil (Miller, 1995).

Cucurbits, which include crops such as cucumber, summer squash, cantaloupe, pumpkin, and watermelon require calcium during a growth period called fruit fill to prevent "blossom end rot". It may also affect tomatoes and peppers. This is a physiological degeneration and secondary fungal infection when insufficient soluble calcium especially during dry weather cause fruits to have fruit curl or have pointed tips, and these fruits cannot be sold as US 1 or US 2 grade (Breman, personal communication, 2000). These grades attract the highest price on the market, so it is desirable for the fruit not to show these characteristics.

Blossom end rot on tomato plant (left) and pepper plant (right).

Vegetable crops that have a sulfur deficiency show a general yellowing of younger leaves and reduced growth. This occurs on very sandy soils.
that are low in organic matter. Soils that follow continued use of sulfur-free fertilizers and areas that receive little atmospheric sulfur show occurrences of sulfur deficiencies most frequently (Maynard and Hochmuth, 1999).

Burger (1993) found that application of ground drywall waste to test plots increased corn yield, soil fertility and concentrations of calcium, magnesium and sulfur in corn ear leaves. The test plots consisted of 15 plots with 5 treatments of three replications with the following: control, agricultural limestone, agricultural gypsum, pulverized drywall, and pulverized drywall at twice the rate of calcium as agricultural lime. Corn grain yield was 25% higher on the plots receiving ground drywall than on control plots. The concentrations of arsenic, barium, cadmium, lead, mercury, selenium, and silver were below detection limits in the grain, and either below detection limits or not higher than other plots for corn ear leaves. Drywall added to the soil at rates that did not exceed the recommended amount for agricultural gypsum was beneficial. The gypsum waste was compared to agricultural gypsum and limestone with favorable results.

Crushed drywall waste was also found to be comparable in effectiveness to commercial gypsum fertilizer when applied to potato crops in Wisconsin (Wolkowski, 1998). The study was conducted because there are manufactured housing plants that produce a significant amount of drywall waste close to major regions of potato production. Since many potato farmers already used commercial gypsum to fertilize their potato crops, the use of crushed drywall waste in its place would provide a low cost alternative in addition to reducing the waste management costs of housing manufacturers and potentially develop business opportunities for recycling companies. The crushed drywall waste was compared to commercial gypsum fertilizer that was applied to three different soil types with potato crops. It did not negatively affect crop growth or yield. Also, soil calcium levels were increased at one site and soil sulfur levels were increased at two sites.

Mushrooms are another crop that can utilize gypsum. They are typically grown in an environment that includes gypsum in the form of compost. Some examples of mixtures used to grow mushrooms include adding 30 pounds of gypsum for every ton of horse manure; or 15 tons of corn cobs, 7 tons of meadow hay, 4 tons of clover or alfalfa hay, and ½ ton of gypsum. Mushrooms are grown in the United States except in the south, where the climate is too harsh, as they require cooler temperatures. Eastern Pennsylvania is the largest mushroom producing region in the U.S. (University of Washington, 1976).

GYPSUM FOR IMPROVING SOIL STRUCTURE

Gypsum can be used to improve soil structure by providing calcium, which is necessary to flocculate clay soils. Flocculation is the process in which many individual small clay particles bind together to form fewer,
but larger, clay particles (Shainberg et al. 1989). Gypsum may be used to improve clayey soils because they typically have high magnesium levels and little organic matter. This condition tends to make the soil particles so tight that air and water cannot penetrate it. By adding gypsum to clayey soils, ion exchange results, which improves soil tilth and friability. Tilth and friability simply refer to the soils’ structural properties. This means that it is in a more “workable” condition because it is loose and no longer compacted. This, in turn, allows water and air to penetrate the soil, which promotes root growth and plant strength.

Dispersive soils occur in arid, semiarid and humid climates. They have an unstable structure, which allows them to be eroded easily (Shainberg et al., 1989). This characteristic causes these types of soils to disperse and develop a compacted structure mostly at or near the soil surface, making them difficult to manage. Dispersive soils are also compacted by mechanical stresses such as raindrop impact and cultivation when moist. Some of the problems associated with dispersive soils as outlined by Shainberg et al. (1989) include surface crusting, high runoff and erosion, reduced water infiltration, and restricted plant establishment and growth.

Prior to the EPA statute restricting the use of phosphogypsum in agriculture (Federal Register, 1992), studies were conducted using phosphogypsum to improve soil structure, which showed favorable results. For example, spreading phosphogypsum on sandy loam soil with distilled rainwater prevented clay dispersion, tripled the permeability of the soil and decreased runoff depth and soil loss (Warrington et al., 1989). Also, spreading 5 megagrams per hectare of phosphogypsum on 6 different soil surfaces decreased soil loss greatly from dispersive soils, and moderately from non-dispersive soils (Ben-Hur et al., 1992).

**Reclamation of Sodic Soils**

Sodic, or alkali soils, are those soils that have high sodium levels and various soluble salts. Elevated sodium levels such as those in sodic soils can prevent plant or crop production. Reclamation of sodic soils involves removal of sodium (Na\(^+\)) and replacing it with calcium (Ca\(^{2+}\)) to provide a better environment for crops to establish themselves and increase root penetration. Gypsum dissolves in the soil to provide a level of permeability such that water can enter into the soil profile and allow for the exchange of sodium for calcium. Typically, sodic soils will disperse in water. This means that they will absorb water during a rain until they disperse into individual particles (Russell, 1973). As the individual particles disperse, they form a crust on the surface of the soil. This causes water percolation through the soil profile to be reduced or completely blocked.
According to a study by the USDA (1954), electrolytes in the soil provided by gypsum maintain permeability to allow water into the soil profile, and to exchange calcium for sodium. Gypsum can prevent swelling and dispersion, increase soil tilth and reduce surface crusting with respect to sodic soils (Shainberg et al., 1989). In a study by Ilyas et al. (1997), a gypsum application of 25 Mg/ha was found to increase soluble sodium in the top 20 cm of the soil when tested on a low permeability, saline-sodic soil with crop rotation. Gypsum also removes bicarbonate ions from soil solution, which can lower soil pH (Lindsay, 1979 and Rengal et al., 1999). Singh et al. (1997) found that removing bicarbonate ions from the soil with the addition of gypsum clearly benefited alkaline, sodic soils in India. In Australia, red-brown wheat soils (Alfisols) have been studied to evaluate gypsum use to increase crop yields. These soils have very poor physical properties which do not allow proper infiltration of water, therefore decreasing crop yields. Wheat yields with increases of 20% or more and as high as 50% have been reported (Howell, 1987). Increases in wheat yields are directly attributed to higher moisture content in the soil from the addition of gypsum.

CORRECTION OF SUBSOIL ACIDITY

Shainberg et al. (1989) has postulated that the greatest potential for economic use of gypsum may lie in crusting soils with acid subsoil horizons. The condition of subsoil acidity is described as soils having toxic levels of aluminum, and often deficient amounts of calcium, that partially or completely deter roots from entering the subsoil. This prevents the plant from gaining moisture below the surface and may hinder plant yield and root growth due to water stress. Lime has been used to treat this condition. It does not, however, work in all cases, as many acid subsoils have variable charges and do not allow for movement of lime down the soil profile (Sumner, 1990). This method is not effective due to the labor intensity of incorporating the lime to subsoil depths.

Yield responses on acid soils to gypsum have been shown in Brazil, South Africa, and the United States. Subsoil acidity is a severe problem in Brazil due to high annual rainfall, which causes the soil to erode and leach very quickly.

Sumner (1990) studied the effects of applying phosphogypsum versus mined gypsum to highly weathered soils in Georgia in order to ameliorate subsoil acidity. The crops studied included alfalfa, corn, soybeans, cotton and peaches. Phosphogypsum was found to be a suitable ameliorant in correcting subsoil acidity and was also found to be equivalent to gypsum in this respect. Given one to two years, gypsum was found to dissolve and move into the subsoil where it supplied calcium for root elongation. This, in turn, allowed the crop to reach water that was previously beyond reach and increased crop yields. A treatment of an initial 10 tons of gypsum per hectare lasted more than five years, making it economically feasible to use gypsum for
amelioration. Also, net profit due to gypsum application ranged from $100 to $500 per hectare per year for alfalfa, peaches and cotton.

Although Florida does not experience all of the soil problems discussed here, they are present in other parts of the United States as well as foreign countries. The southeastern U.S. does experience problems with dispersion-induced crusting (FIPR A, 1989) and soils that are low in calcium and sulfur (FIPR B, 1989). Soils with low calcium and sulfur levels are located along or adjacent to the coastal plains of the eastern seaboard, or those from Florida that are located north of Ft. Myers and Belle Glade (FIPR B, 1989). Therefore, gypsum is needed for soils in Florida as well as other parts of the U.S. and abroad.

OTHER AGRICULTURAL BENEFITS

Scrap gypsum drywall has been used as a component in mixtures with wood shavings as an animal bedding material (Wyatt and Goodman, 1992). The study was based on the idea that scrap gypsum drywall would control moisture levels. The mortality, feed conversion, and incidence of leg abnormalities of broiler chicks was studied using scrap gypsum drywall as a bedding material. It was used alone or with fir wood shavings and compared to fir wood shavings alone. The composition of the scrap drywall was 71% to 89% gypsum, 2% to 19% limestone, 1% to 2% paper, and 1% to 2% crystalline silica. A lower body weight gain was observed after 21 days for chicks reared on scrap drywall alone when compared to the other two treatments. After 41 days (the end of the growth cycle), however, there was no difference in body weight gain between the three treatments. It was recommended by the authors that a layer of wood shavings should overlay the material, as it was quite dusty. The study did conclude that scrap gypsum might assist in controlling litter moisture levels.

Scrap gypsum drywall used as a bedding material for animals was also studied by the Clean Washington Center (1995). There were problems with anaerobic conditions occurring because a farmer was land applying the material, and a cease and desist order was made. However, it was concluded that if these conditions were prevented from occurring, it would be an acceptable practice. Some health officials felt ambivalent about this practice.

Gypsum may also prevent certain plant diseases. Aflatoxins are secondary metabolites produced by molds that grow on a variety of crops, including peanuts. They are a concern because they are carcinogenic, mutagenic and teratogenic compounds. Human exposure to aflatoxins can result directly from ingestion of contaminated foods or from eating meat that has been infected from feed prior to human consumption (Rustom, 1997). Peanuts grown in gypsum treated fields were found to have less aflatoxin produced on them when compared to peanuts grown without gypsum amendments (Reding and Harrison,
Recycling of Gypsum Drywall

1994). Calcium content increased as the application rate of gypsum increased and fungal growth was inhibited in peanuts receiving the gypsum supplement.

Gypsum was found effective in reducing the amount of soluble phosphorous leached from manure-loaded soils from dairy use (Anderson et al., 1995). Phosphorous from dairy animal manure is a contaminant to surface waters near Lake Okeechobee in south Florida. It is a nutrient known to accelerate eutrophic conditions by leaching into surface waters in this area. The soils with high phosphorous concentrations are found under dairy and beef land use areas, such as those close to milking barns, holding pens and feeding lots for cattle. These soils are typically acid and low in calcium. Two studies were conducted using gypsum. The first was the gypsum amendment study, which was to verify the effectiveness of gypsum amendment under high manure-loading conditions. The second was the microbial activity study, which was to determine whether biological activities are influenced by an imposed soil amendment practice.

In the gypsum amendment study, four rates of gypsum (0, 4, 8, and 16 grams per kilogram) using four replications were added to 100 grams of soil containing high levels of total organic carbon from dairy animal land use. In the microbial activity study, treatments consisted of four rates of gypsum (0.1, 1.0, 10, and 100 grams per kilogram) and one control (0 grams per kilogram) applied to the soil. Gypsum was effective in reducing phosphorous at all pH ranges under anaerobic conditions used during the study, and had a positive impact on soil microorganisms. Bacterial suppression occurred, but it was unclear why. Dissolved organic carbon, soluble nitrogen and soluble phosphate used in leaching tests all decreased with increasing applications of gypsum. Gypsum, as a waste material from the construction industry, was concluded to have an impact on soil microorganisms by cycling and mobilization of nutrients.

USE IN PRODUCING COMPOST

Gypsum drywall waste can also be used as a bulking agent in compost and has been demonstrated to be successful in several instances. Bulking agents are typically coarse material that will break down slowly in the compost and improve the structure by allowing air circulation. Bulking agents are important when there is not a good mixture of materials or when raw materials tend to pack together. Gypsum waste can reduce nitrogen loss to the atmosphere, control odors and add calcium and sulfur. Case studies where gypsum waste was used as a bulking agent in compost are reviewed in this section.
Closeup of unscreened compost material amended with processed scrap gypsum drywall.

The Clean Washington Center found that scrap drywall could be incorporated into the composting process as a bulking agent without hindering product quality (CWC, 1999). Porosity, temperature, oxygen, moisture, odor, decomposition, and pH were monitored over an 8-week period. Calcium, boron and organic content were determined at the end of the study. The mix reached temperatures adequate to destroy pathogens by EPA regulations. It was also suggested that drywall be used to supplement other bulking agents when composting biosolids, to balance the carbon to nitrogen ratio (C:N), absorb excess water and provide necessary porosity. It was proposed that waste paper from drywall be composted to serve as a carbon source and moisture absorber.

Another case study took place at Wood Recycle in Wichita, Kansas. Drywall was composted after a large drywall distributor in the area started sending five to six tons per week to the facility (Block, 1999). Also, a homebuilders’ association was approached about segregating drywall for recycling at nearby job sites. The process Wood Recycle uses is relatively simple. The drywall was ground up before composting in windrows that were 300-350 feet long, 12 to 14 feet wide and four to six feet high which were turned weekly. Moisture levels were kept between 40 and 50 percent and the optimum temperature was approximately 150°F. The compost was screened to ½-inch minus and sold for $15.00 per cubic yard.

The USDA opened a compost facility in Beltsville, Maryland at its Agricultural Research Center where drywall and other construction scraps and byproducts from the electric power industry are used as residue for composting (USDA, 1998). Researchers worked with the Gypsum Association of Washington, D.C. and the National Association of Home Builders’ Research Center in Upper Marlboro, Maryland on this project. The project is helping to keep up with Maryland’s voluntary nutrient management program, which keeps nitrogen and phosphorous out of the Chesapeake Bay.
ENVIRONMENTAL ISSUES WITH REUSE OF GYPSUM DRYWALL IN AGRICULTURE

Gypsum drywall components such as asphalt-based wax emulsions, starch-based glues, organics and boron are noted by Burger (1993) as ingredients other than gypsum in drywall. Starch-based glues should be biodegradable, and asphalt-based wax emulsions are used in moisture resistant drywall, which is not typically used in recycling for land application purposes. Boron is a concern due to the potential of phytotoxicity to some plants (light tips on clover leaves in picture below). According to Korcak (1996), phytotoxicity usually occurs when plants are seeded with or planted with materials containing high levels of boron, and can be avoided by applying scrap gypsum material some time prior to the establishment of the plant. This would mean applying the gypsum material in the fall if the planting or seeding were to take place in the spring. Burger (1993) further suggests that phytotoxicity should not be a problem if boron concentrations in the drywall are not excessive and the application rates are held within the recommended 5 to 10 tons per acre (equivalent basis) range. Phytotoxicity is not a problem specific to Florida, but can occur anywhere there is an excessive amount of boron present in soil or plant tissue.

The suitability of scrap drywall as a cropland amendment with an emphasis on boron content was evaluated by Dixon (1984). A waste drywall pile was evaluated to find boron concentrations in the range of 92 to 156 ppm, which is equivalent to 0.18 to 0.31 pounds of boron per ton of material. Common application rates of gypsum in California range from one to four tons per acre except for saline or alkali soils, which go up to 8 tons per acre. Dixon found that a four ton per acre application of scrap drywall using the highest boron concentration of 156 ppm only added 1.25 pounds of boron. This amount is within the recommended fertilization range for boron. Dixon also found that cadmium, lead, arsenic and selenium were not a serious concern if common crop production practices were followed for gypsum application. Scrap gypsum drywall was found to be suitable for agricultural use, but should be evaluated on a case-by-case basis where soil boron is high or where irrigation water contains elevated boron levels. Chemical monitoring of the material was recommended to fulfill guaranteed analysis, and further recommendations were to process the material to a particle size that would pass a 60 mesh Tyler screen.

Korcak (1996) found that the boron concentration was higher in agricultural gypsum than in pulverized drywall. Pulverized drywall was obtained from U.S. Gypsum Corporation’s Stony Point facility in 55-gallon drums and agricultural gypsum was bagged Ben Franklin Landplaster by U.S. Gypsum. The pulverized drywall had a
Appendix A

concentration of 20 ppm boron and the agricultural gypsum contained 97 ppm boron. An application rate of 5 tons per acre was used for both, which was equivalent to 0.20 pounds boron (from pulverized drywall) and 0.97 pounds of boron (from agricultural gypsum) per acre.

GYPSUM USE IN CONSTRUCTION MATERIALS

Another potential use for recovered gypsum drywall is in construction materials. Gypsum has been used in concrete, stucco, plaster and blocks. Gypsum may potentially be combined with other materials like fly ash and cork for recycling into bricks and other products. Most of the investigation of gypsum recycling in construction materials has primarily been for phosphogypsum, or the by-product gypsum produced from acid manufacturing industries or gypsum produced from the flue gas desulfurization process at coal-fired power plants. However, due to the similarity in composition between the two materials, it is likely that gypsum could be used for the same purposes.

GYPSUM AS AGGREGATE IN CONCRETE

The potential use of scrap gypsum drywall as an aggregate in concrete was reviewed by Hemmings and Venta (1994). Gypsum is an essential part of the Portland cement manufacturing process; however, all of the calcium sulfate is consumed in the manufacturing process. The use of drywall as aggregate in cement is possible, however, sulfate content is a concern. High sulfate content in concrete affects the soundness of the material and testing beyond standardized testing is required for concretes with higher than normal sulfate levels. Severe deterioration, shown by expansion and cracking may occur in concrete with high sulfate levels. The sulfate reacts with the calcium hydroxide and aluminates in the cement forming an expanding crystal that causes expansive stress and damage to the concrete (Hemmings and Venta, 1994).

ROAD CONSTRUCTION

Phosphogypsum and fluorogypsum have been used for road stabilization in several studies (Chang and Mantell, 1990 and Vipulanandan and Basheer, 1998). Phosphogypsum is produced from the wet acid manufacture of phosphoric acid, as explained in a previous section. Fluorogypsum is a byproduct of the production of hydrofluoric acid from fluorospar, a mineral composed of calcium fluoride and sulfuric acid. Again, due to similarities in the composition of by-product gypsum and gypsum drywall, it can be inferred that road stabilization would be a potential market for reuse.

Road base stabilization can include many activities that are meant to improve the strength and stability of road base materials. In general,
stabilizing road base materials can result in improvement of strength of the road base, help the road last longer, reduce routine maintenance requirements, reduce required thickness of pavement overlays, and reduce aggregate material loss for unpaved roads. Recycled materials have also been used in embankment construction due to a lack of suitable borrow material. Typically, geotechnical properties such as moisture content, Atterburg limits, unconfined compressive strength, California Bearing Ratio (CBR), and compaction are measured to evaluate the effectiveness of the waste material as a replacement for quality soils in road construction.

Two case studies using phosphogypsum for road base material were reviewed by Chang and Mantell (1990) for the Phosphate Research Institute. The first case study was carried out in LaPorte, Texas with Mobil Mining and Mineral Company, Texas A&M University, and McBride-Ratcliff, Inc. (a local geotechnical firm). Each street constructed had seven sections, two of which were controls that had 8” bases of crushed limestone. The other five sections contained different phosphogypsum (PG) mixtures. These were: 90% PG and 10% Portland Cement (PC), 75% PG and 25% fly ash, 85% PG and 15% fly ash, 95% PG and 5% PC, and 82.5% PG and 7.5% PC. The sections were evaluated and found to be acceptable road base materials based on the fact that degradation did not occur at the time of the follow up report three years after construction. The PG and PC mixtures had the highest effective thickness at the time of follow up evaluation.

The other study took place in Polk County, Florida on an experimental road. The previous method of road stabilization used in this area was adding fine-grained soils (clay) to granular soils (sand), but proved to result in problems during the rainy season. Testing of the experimental road was a joint effort by the University of Miami, Florida Department of Transportation (FDOT) and Polk County. Nuclear density measurements, moisture determinations, and the California Bearing Ratio (CBR) test were performed to determine the subgrade bearing ratio of the soil. After adding phosphogypsum to the soil and compacting, the CBR was improved from 17 to 133. It was found that, under optimum moisture conditions, the CBR may be improved up to 100%. Groundwater was sampled for 31 months and was reported to have “no measurable influence on the water quality at the site.” The construction crew for the project also gave an assessment of the experiment and found that phosphogypsum mixtures were easier to work with than clay mixtures, operating costs are less expensive, and that the stability of the mixtures is greater than that of clay mixtures. It was also found that these mixtures did not cause delays in construction because the compacted mixture did not absorb water as the clay mixtures do. Overall, phosphogypsum was considered to be a good binder for road base material (Chang and Mantell, 1990).
Fluorogypsum was found to be a suitable material for subgrade construction based on CBR test results by Vipulanandan and Basheer (1998). A water leaching test and TCLP (Toxicity Characteristic Leaching Procedure) were used to determine the effects of this material on the environment. Leachate was analyzed for metals and sulfates using ICP (Inductively Coupled Plasma) and IC (Ion Chromatography), respectively. Because fluorogypsum is largely calcium sulfate, the leachate from the water leaching test had a high concentration of sulfate. In the TCLP test, calcium concentrations were higher than in the water test due to agitation and acidic leachate solution. Sulfate concentrations were lower, indicating that sulfate is not readily leached from the solid matrix as metals are in an acidic environment. Overall, fluorogypsum was rated as a suitable material for subgrade construction.

GYPSUM AS AN ON-SITE SOIL AMENDMENT

Pulverized gypsum drywall was found to be a suitable substitute under conditions where agricultural gypsum would be recommended as a soil amendment around new home construction sites (Korcak, 1996). The pulverized gypsum drywall material was analyzed for content, applied to turf grass, tomato and broccoli plants, and used in a soil column leaching study. The study found no abnormally high elemental contents from an agricultural viewpoint. No differences were found between pulverized drywall and agricultural gypsum after running TCLP tests and a dioxin screen and neither material posed a leachate contamination problem from the soil column leaching study. It was concluded to be similar in content to agricultural gypsum.

The pulverized drywall and agricultural gypsum were also applied to turf grass to study biomass production (Korcak, 1996). Neither material had a significant effect on turf grass biomass production. The elemental content of grass samples showed the same compositional differences expected from the addition of gypsum to soils. In the leaching study, no indications of trace element leaching which could cause groundwater contamination problems were found. A trend toward enhanced mobility of aluminum through the soil column was also found, which could be beneficial on plant root growth. The tomato and broccoli growth on amended soils in pots was inconclusive because deer ate some of the broccoli heads. Tomato fruit yields and fruit composition were, for the most part, little affected by the application of either material. The author noted that the results are from plants grown in amended soils grown in confined pots and not in open soil.

Recommendations for applying pulverized gypsum drywall waste to new home construction sites include having an elemental analysis of the drywall used, develop a biological “quick” test, and prediction of a beneficial use based on soil surveys (Korcak, 1996). Manufacturers can supply product information or a database with analyses performed on
Recycling of Gypsum Drywall

drywall from different manufacturers may be kept. The biological “quick”
test mentioned previously could determine within 4 to 7 days whether or
not a specific soil will respond to scrap gypsum drywall application. Since virtually all counties have been mapped with respect to soil type
and include information about the major soil types in the region, it would
be a relatively simple task to identify which soils would be responsive to
scrap gypsum after performing the “quick” test for soils in a given county. Builders could use this information at specific construction sites
to determine whether they could recycle their scrap drywall waste on-
site.

OTHER RECYCLING MARKETS

Gypsum has other uses in addition to its role in agriculture and
construction, according to The California Integrated Waste Management
Board (CIWMB) (1998). Recycled gypsum was used in bulking and
drying sludge and to settle dirt and clay particles in turbid water. In
turbid water, gypsum will cause the clay particles to flocculate and settle
to the bottom, decreasing the turbidity. Both of these studies were
funded by the State of New York. Recycled gypsum could also be used to
make flea powder, since it comprises approximately 90 percent of the
inert material in some flea powders. Due to its absorbent properties,
gypsum waste could be used by mechanics to absorb spilled grease. Recycled gypsum waste could be used instead of lime to mark lines on
athletic fields as well.

COLLECTION AND PROCESSING

COLLECTION AND TRANSPORTATION

Gypsum waste material must be collected in a manner that saves
time and money in order to make the recycling process profitable. Job
site source separation has been an effective method to collect specific
wastes in a relatively clean fashion while keeping cost and contamination
at a minimum.

C&D debris is typically collected in 20 cubic yard roll-off containers
that are placed on the construction site. At other sites, material is
collected in a pile or in a corral, which is then removed by a waste
collection service. Most construction sites do not have a separate
container for drywall, however, Doherty’s Construction Management in
Bellevue, Washington uses several small containers (13 to 16 cubic
yards) placed strategically on construction sites to facilitate recycling.
They place the containers close to the work areas and work with the
builder to find the most convenient places to put multiple containers.
This keeps labor cost down because the workers do not have to travel as
far to deposit recyclable materials.
Transportation costs are an important factor in gypsum recycling. Since gypsum is a bulky, heavy material, it often has greater transportation costs than lighter C&D constituents. It has been estimated that, if transported greater than 50 miles, gypsum waste is not economical to recycle unless tipping fees in the area are very high. This is where competition in the market comes into play, because even if the tipping fees are high, other products on the market may be more economical than waste gypsum drywall.

**PROCESSING OPTIONS AND ISSUES**

Equipment and product specifications for several processing options are investigated in this report. Gypsum waste can be processed by equipment ranging from a small chipper to a large trommel screen and conveyor. This section is intended to present an overview of the equipment used to process gypsum drywall waste and the various types of end products made in the process.

The origin of the waste must be known prior to processing to make sure there are no contaminants in the waste. There are two types of gypsum drywall waste: construction and demolition. In general, gypsum drywall waste from demolition sites contains contaminants such as nails, tape, joint compound, and paint. This simply means that it takes more time to process because workers have to pull contaminants out of waste piles. The equipment, therefore, runs less smoothly and it cannot be used for agricultural purposes. Occasionally, contaminants are present in new construction waste, but not as frequently as in demolition waste.

Nails can cause equipment failure for some machines and should be removed prior to processing. They can cause the end product to be unusable. If the end product were to be reused as new drywall, nails may potentially hurt workers or residents if the wallboard is broken. Tape, which is used to smooth the joints of the drywall, needs to be screened out unless it is intended for use in compost where it will break down. It cannot be allowed in the end product if it is to be used as an ingredient in cement. Joint compound is comprised of limestone or gypsum, but can contain asbestos as a contaminant. This is a concern especially if the structure from which it came was built before the mid-1970’s (CIWMB 1998). Paint is typically used to cover drywall in homes. Paint used in structures built prior to 1978 may contain lead. Drywall that has lead-based paint on it should not be recycled. It should be disposed of properly since it is toxic (CIWMB, 1998). Most processors take only clean gypsum waste because it is more expensive to handle demolition materials that are potentially contaminated.

The Construction Materials Recycling Association (CMRA) (Turley, 1998) has outlined some of the methods used to process waste gypsum drywall. The first method, which claims to remove almost all paper and approximately 98% metals, is used by Kolberg-Pioneer. Their process is
Recycling of Gypsum Drywall

to use a trommel screen and some form of rolling stock, which could be a wheel loader. If the material is left outside to get wet, it breaks down the glue adhesive that holds the paper backing to the gypsum core, separating the gypsum into a powder and the paper in larger pieces. A front-end loader is then driven over the material to break it up even more prior to placing it on the trommel screen. The recommended setting for the screen mesh is 7/8” or smaller so that virtually all of the gypsum falls through the screen and the paper is taken out on the conveyor to a different pile. The screen may be set at a smaller mesh or removing nails or other metal contaminants magnetically if they are detrimental to the product.

A horizontal grinder is used by All Seasons Enterprises in Iowa to process out of spec and waste gypsum drywall. The gypsum enters the system through a feed hopper and is forced into an enclosed grinding chamber by a hydraulic ram. The gypsum is ground up via a horizontal rotor with cutter bits against stationary shearbars. The gap between the rotor and shearbars controls the product size, but a screen that is after the rotor controls the final sizing. The product is then sent to a conveyor.

Another processing system uses a grinder with a flexible impaction system to remove paper backing from the core before breaking it down to the final product size. The material is sent through a trommel screen with three output settings (1/8-inch, ½-inch and paper) after being passed through a magnet. All of the problems such as material contamination, dust containment, and weather protection are avoided because the system is in an enclosed container.

Another system to process gypsum drywall tumbles the material in a 25-foot long drum. Doors on opposite sides of the drum are operated by hydraulic pinion gears to load the material. The material is tumbled inside the drum, which has paddles welded inside to help crush the material and turn the load, for approximately 30 minutes at 7 rpm. Close to the end of the cycle, the doors are opened, allowing the material to fall out of the drum over several rotations.

A pilot program conducted by the National Association of Home Builders (NAHB), U.S. Environmental Protection Agency (USEPA) and Indiana Department of Environmental Management (IDEM) evaluated the feasibility of the on-site grinding of wood, drywall and cardboard components of new residential construction waste as an alternative to landfilling. The material was land applied based on research that demonstrated beneficial effects to the soil and plants. The state evaluated the processing systems available after sending out letters to manufacturers of machines that may be used for the project. They got a weak response from the industry, and found that most of the companies that responded had equipment that did not meet the specifications for the job. Some equipment that did meet the requirements was tested in demonstration projects to evaluate their performance prior to
purchasing. The grinders were evaluated on criteria such as mobility, particle size, customer friendly operation, and cost. The machine needed to be small and easy to maneuver on building lots, a minus one inch particle size, not produce excess noise, dust or paper in the air, and cost less than $100,000. The selected grinder was a top-loading, low-speed, horizontal drive grinder manufactured by Concept Products Corporation of Paoli, Pennsylvania named the “Shred-All”. It uses a 28-80 RPM, six-foot long auger-shaft with 35 replaceable teeth, powered by a 125 horsepower diesel engine. The trailer assembly was eight feet long and six feet wide, weighing about 8,000 pounds, and pulled by a one-ton pick up truck.

The grinder’s throughput was an average of 10.5 to 11 cubic yards per hour, which was loaded manually by two workers. The processed material was reduced in volume by about 60 percent. The gypsum waste was essentially processed into dust and the paper backing was processed into fragments of three inches or less. There were a few problems with overheating and dust, but these problems were minor. A water misting system was installed to reduce dust during part of the project and only one complaint was received during the six-month project. It included three misting heads in the hopper/auger area, supply lines and an electric pump. The water was supplied through a residential water hose. This water supply may not be available at other sites at the right time.

The overall economic feasibility was found to be cost competitive with landfilling. The project is basing these conclusions on moderately high tipping fees, modest labor rates, and low transportation costs. Since some drywall contractors haul their own waste off site and include this in their total price for the house, it should be noted that grinding the drywall onsite eliminated this extra cost, which was found to be approximately $50 to $100 per house. The recommended source for processed scrap drywall to be land applied was regular, clean drywall, pulverized to a minus one inch size, and spread evenly around the site at rates up to eight tons per acre.

A hammer mill can be used to process gypsum drywall waste (CIWMB 1998). The hammer mill produces material that is 93 percent gypsum powder and seven percent shredded paper by weight. Paper waste from gypsum drywall recycling can be recycled into new drywall paper, paperboard, packaging or compost.

**EXISTING RECYCLING PROGRAMS**

Drywall programs are as diverse as the states that have developed them. Not every state or country has drywall recycling programs. In response to problems associated with landfilling waste gypsum drywall, the Washington State Department of Ecology (1990) published a progress
Recycling of Gypsum Drywall

report on gypsum waste with recommendations for best available technologies. The technologies were ranked after being evaluated against a set of environmental, economic, waste management, and technical criteria. Eliminating gypsum wastes from landfills using alternative waste management methods was one of the main approaches to the problem. These methods included recycling, incineration, ocean disposal, and use as an agricultural fertilizer. Recycling waste drywall back into new wallboard ranked first, use of gypsum drywall waste in agriculture ranked second, and best possible landfill control practices and ocean dumping tied for the third rank.

Recycling received the first rank because it is most important for the state, environmental and health impacts are positive, and the technology is proven, available, and cost-effective. Some issues that were associated with recycling were availability of recycling facilities to drywall waste producers, feasibility of separating the waste from other C&D debris, and transportation costs of delivering the waste to a recycling facility from the construction site. Use of drywall waste in agriculture ranked second because it would be an ideal situation for reusing the waste. No studies were cited in the report and the authors felt it was unclear whether or not this option was feasible at that time. Since then, many studies have been undertaken and gypsum has proven to be an adequate substitute for agricultural gypsum. Best possible management practices and ocean dumping ranked third because both technologies were considered basically environmentally safe and feasible. The best possible management practices technology appeared to be the best solution for drywall waste management at landfills that were located far from recycling facilities, but did not address reducing the amount of waste being disposed of at the landfill. Ocean dumping was found to be expensive and difficult to implement, since opposition was strong against dumping anything in Puget Sound. Obtaining permits and site location processes were found to complicate this technology. The following sections describe current major recycling programs in detail. Appendix A contains a table of brief summaries of other programs that have been or are in place.

NEW WEST GYPSUM INC.

New West Gypsum (NWG) (Harker, 2000) is the largest drywall recycling company in North America, and has recycled over one million tons of drywall since it started processing for Domtar, now owned by Georgia Pacific, in 1987. The business spawned from legislation in British Columbia to divert gypsum drywall waste from disposal in landfills in 1983. They have successfully established themselves as the leader in the drywall recycling industry by expanding operations and patenting their process. NWG has operations in New Westminster, B.C, Toronto, Seattle and Vancouver. NWG has established transfer stations for its clients, making it convenient for them to dispose of their waste. They take recycled product back to drywall manufacturers to be used in
the manufacture of new board, which accounts for approximately 15-20 percent of the raw feedstock at these facilities. Most recyclers of gypsum drywall waste do not recycle the paper backing. NWG recycles the paper backing of drywall in addition to the gypsum core. A paper defibering system is under development at NWG which will clean the drywall paper so that it may be returned to paper companies and made into new paper products, like the backing for drywall. The company is planning to expand operations by franchising or licensing their technology to other areas in North America, Australia, Japan and Europe.

Waste Reduction Products Corporation

Gypsum drywall scrap is one of the biggest components of the C&D waste stream in North Carolina, which has the second largest manufactured home industry in the United States. Waste Reduction Products Corp. of Goldston, North Carolina has found a way to economically produce products from reclaimed waste drywall scrap (Ewadinger and Gray, 1998). They were established in 1993 with help from the Recycling Business Assistance Center to develop markets for C&D debris in North Carolina. They have created economic benefits for drywall scrap generators by cutting tipping fees by 50% formerly paid to landfills and reducing the number of pulls to empty collection containers. Offering a low cost alternative to disposal is the key to success. Essentially, state officials convert drywall into calcium sulfate powder and cellulose fiber, forming pellets or using both as base materials for other products. End user markets are home gardening, lawn care, golf course maintenance, spill absorbents, animal waste management and cat litter. Currently, there are plans to expand operations into three other states.

AgriCycle, Ltd.

AgriCycle operates a gypsum drywall processing facility in Columbus, Ohio as well as mobile processing centers located at several large drywall manufacturing plants. The facility in Columbus, Ohio is located in a large warehouse in an industrial park and processes approximately 250 tons of scrap drywall per week from residential construction projects only. They also operate a 24-hour construction site waste pickup service (a scrapping service) for drywall. AgriCycle sells the processed gypsum for use in agriculture and cement manufacturing.
Drop-off area for incoming loads of scrap drywall.

Since drywall contractors in the Columbus area are responsible for the disposal of their own waste, they leave the scrap drywall at the point of generation and hire AgriCycle to clean up the site. This includes removing all scraps of drywall as well as sweeping up the drywall dust. AgriCycle subcontracts with a number of private haulers to perform the cleanup service at the site, and only scrap drywall is collected. The drywall contractor pays AgriCycle based on the number of linear feet of drywall in the construction project ($0.01 per foot). The drywall is collected and then transported to the processing facility.
Loading scrap drywall onto trommel screen for processing.

Processed gypsum pile inside the facility.

The collection process has proven to be successful in the Columbus area. Scrap drywall is kept at the site at which it was generated until the project is completed, at which time the drywall contractor calls AgriCycle. AgriCycle noted that many other communities have construction contractors in Ohio that operate in the same type of manner. All of the dispatching and routing of cleanup trucks occurs from the main facility in Columbus. They maintain a map of local construction projects in their area.
Gyp-Pack Container, Inc.

Gyp-Pack Container, Inc. of Tonowanda, New York has fabricated machines capable of processing gypsum drywall since February 1993 (Steuteville, 1994). These machines strip the paper from the drywall by using knives as well series of grinding and screening operations, and bale the product into cubes that weigh approximately 1.5 tons. The main markets for the product are new drywall factories and the agricultural industry, which buy the material for an average of $25 per ton.

Doherty Construction Waste Management

Doherty Construction Waste Management in Bellevue, Washington saved $44,000 in costs, compared to another site that did not recycle, by recycling wood, gypsum drywall and corrugated cardboard on site (Biocycle, 1996). State officials also found that recycling decreased the overall amount of waste generated at the site by 50%, indicating that it made the workers less wasteful. Doherty provides an incentive to separate materials by charging fees that are lower than disposal costs. Doherty used 13 to 16 cubic yard roll-off containers at various places on site to collect the materials. The roll-off containers and trucks were relatively small, facilitating collection because they were in close proximity to the work area. Labor costs are reduced because site workers do not have to walk as far to deposit the waste. State officials say that the key to cutting disposal fees is to recycle the biggest volume materials such as wood and gypsum drywall. Most of the company’s projects are not as large as this one. In other projects, workers make separate piles of specified waste (typically drywall and wood), and load this onto trucks manually. Manual loading ensures a clean load for the recycling processor and can double the tonnage of material per truckload.
because it is packed more tightly this way. In projects where there is more material produced, a roll-off container is placed at the site.

**DRYWALL COMPANY RECYCLING**

Celotex and Lafarge Gypsum companies focus their recycling efforts internally on waste drywall at their manufacturing plant sites. They are able to recycle about 1-2% of the waste drywall at their facilities. Georgia-Pacific Gypsum takes unprocessed drywall at no payment or fee, but charges $4 per ton for crushed or ground drywall and doesn’t remove the paper. James Hardie Gypsum accepts scrap from construction job sites and charges for the service. State officials remove the paper during the recycling process.
## Appendix B

### RESULTS OF TESTING FROM FLORIDA CRUSHED STONE

<table>
<thead>
<tr>
<th></th>
<th>DOT/ AASHTO II Minimum</th>
<th>DOT/ AASHTO II Maximum</th>
<th>Cement Made with Virgin Gypsum Rock</th>
<th>Cement Made with Orange County Drywall</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>20</td>
<td>-</td>
<td>20.81</td>
<td>14.38</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>-</td>
<td>6.0</td>
<td>5.15</td>
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<tr>
<td>Fe₂O₃</td>
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<td>6.0</td>
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<td>CaO</td>
<td>-</td>
<td>-</td>
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</tr>
<tr>
<td>MgO</td>
<td>-</td>
<td>6.0</td>
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<td>K₂O</td>
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<td>Cl</td>
<td>-</td>
<td>-</td>
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<td></td>
</tr>
<tr>
<td>% Gypsum</td>
<td>-</td>
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<tr>
<td>% Moisture</td>
<td>-</td>
<td>-</td>
<td>23.50</td>
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</tr>
</tbody>
</table>
Appendix C

ARTICLES, NEWS RELEASES, AND PRESENTATIONS ON DRYWALL RECYCLING IN ORANGE AND SEMINOLE COUNTIES
Pilot Project Gives New Life to Used Drywall

Monday January 6, 12:45 pm ET

ORLANDO, Fla., Jan. 6 /PRNewswire/ -- An ongoing pilot program in Orange and Seminole (Fla.) counties, being overseen by management consulting and engineering firms R. W. Beck, Inc. and SCS Engineers, explores the recycling potential of drywall -- to reduce volume and foul odors in landfills.

- (Photo: NewsCom: http://www.newscom.com/cgi-bin/prnh/20030106/FLM016)

During the program, tons of wasted drywall will be separated into two separate products, paper and gypsum. Gypsum, commonly used to make cement and new drywall, also produces agricultural additives for crops such as citrus, tomatoes and peanuts.

"Central Florida has so much drywall, from housing construction as well as commercial expansion such as the Orange County Convention Center, that it is a good area to determine if drywall recycling can be sustained," says Steve Cottrell, environmental specialist with the Orange County Solid Waste Division and Utilities Department.

Kim Cochran, project manager for R. W. Beck, says, "One of the goals for the project is testing the drywall recycling technology in a series of on-site demonstrations. So far, all of these tests have proceeded well, and end markets are interested in putting recycled gypsum into their processes as a final test of the material."

Funding for the program is being provided by the Florida Department of Environmental Protection (FDEP) through the Innovative Recycling Grants.

Demonstrations of the drywall recycling process have been conducted by AgriCycle of Ohio, a drywall recycling company, at the Orange County Landfill in eastern Orange County and the 545 Landfill in Winter Garden, Fla. The 545 Landfill is a partner in this project and, along with the Orange County Landfill and Seminole County Transfer Station, is currently accepting drywall for recycling. It is anticipated that drywall recycling will continue after the grant project's completion.

If you would like to find out more about recycling drywall, please contact Mark Hart at the 545 Landfill, (407) 654-0060 or Steve Cottrell at the Orange County Landfill, (407) 836-6600. For more information about the program or to attend the next demonstration, contact R. W. Beck at (407) 422-4911.

Founded in 1942, R. W. Beck is a management consulting and engineering firm with offices nationwide, providing services to both public and private sectors in the areas of energy, water resources, solid waste and telecommunications.

http://biz.yahoo.com/prnews/030106/FLM016_1.html
Today's News

Pilot Project Gives New Life to Used Drywall

R.W. BECK OVERSEES PILOT PROGRAM
A front-end loader crushes a stack of drywall prior to recycling it during a recent demonstration, which is part of an on-going pilot program being overseen by R.W. Beck and SCS Engineers in central Florida.

ORLANDO, FL USA 01/06/2003

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SOURCE R.W. Beck, Inc.

/CONTACT: Jamie Floer, Public Relations Manager, R.W. Beck, +1-407-648-3540, or e-mail, jfloer@rwbeck.com/

/Photo: NewsCom: http://www.newscom.com/cgi-bin/prnh/20030106/FLM016

AP Archive: http://photoarchive.ap.org

PRN Photo Desk, +1-888-776-6555 or +1-212-782-2840/

/Web site: http://www.rwbeck.com/

PR Newswire
United Business Media

More Info

No other information available
Pilot Project Gives New Life to Used Drywall

PR Newswire - Monday January 6, 2003

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http://finance.canada.com/bin/story?StoryId=CpHKnubWbrKXnmde2&Topic=PR Newswi... 1/6/2003
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Pilot Project Gives New Life to Used Drywall

1/6/2003 12:45:00 PM

ORLANDO, Fla., Jan 6, 2003 /PRNewswire via COMTEX/ -- An ongoing pilot program in Orange and Seminole (Fla.) counties, being overseen by management consulting and engineering firms R. W. Beck, Inc. and SCS Engineers, explores the recycling potential of drywall -- to reduce volume and foul odors in landfills.

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http://www.rwbeck.com

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All quotes are in local exchange time.
FL Counties, R.W. Beck Working on Drywall Recycling Pilot Project

1/6/2003

An ongoing pilot program in two counties in Florida -- Orange and Seminole -- and being overseen by R.W. Beck Inc. and SCS Engineers, explores the potential recycling of drywall.

During the program, which began this past summer, tons of wasted drywall will be separated into two separate products, paper and gypsum. Gypsum, commonly used to make cement and new drywall, also produces agricultural additives for crops such as citrus, tomatoes and peanuts.

"Central Florida has so much drywall, from housing construction as well as commercial expansion such as the Orange County Convention Center, that it is a good area to determine if drywall recycling can be sustained," says Steve Cottrell, environmental specialist with the Orange County Solid Waste Division and Utilities Department.

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According to Cochran, the pilot project should run through the end of this May.
The project has been tried in a number of other counties in Florida. The two counties involved in this pilot program are ideally suited to the program because of the significant amount of construction that is taking place.

Monday, January 6, 2003

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Paper and gypsum to be recovered in drywall recycling pilot project

The recycling potential of drywall is being evaluated in a pilot project at two central Florida landfills. The consulting and engineering firm of R W Beck is overseeing the program, with support from the FL Dept of Environmental Protection (FDEP). Paper and gypsum reclaimed from the drywall waste at the 545 and Orange County landfills will be marketed for a variety of applications. The recycling technology was developed by AgriCycle of Ohio. The participating facilities are expected to continue recycling the drywall commercially after the grant money is exhausted. For further information, contact a) Kim Cochran, R W Beck, 800 North Magnolia Ave, Suite 300, Orlando, FL 32803-3261, 407-422-4911, fax 407-648-8382; b) Mark Hart, 545 Landfill, 8050 Avalon Rd, Winter Garden FL 34787, 407-654-0060, fax 407-836-
Bacon's

Pilot project gives new life to used drywall. An ongoing pilot program in Florida's Orange and Seminole counties, being overseen by R. W. Beck, Inc. (Orlando, Florida) and SCS Engineers (Long Beach, California), is exploring the recycling potential of drywall to reduce volume and odors in landfills.

During the program, tons of wasted drywall will be separated into two separate products, paper and gypsum.

"Central Florida has so much drywall, from housing construction as well as commercial expansion such as the Orange County Convention Center, that it is a good area to determine if drywall recycling can be sustained," says Steve Cottrell, environmental specialist with the Orange County Solid Waste Division and Utilities Department.

Kim Cochran, project manager for R. W. Beck, says, "One of the goals for the project is testing the drywall recycling technology in a series of on-site demonstrations."

"So far, all of these tests have proceeded well, and end markets are interested in putting recycled gypsum into their processes as a final test of the material."
2002 was $11,615 on 19 transactions totaling some $250 million.
Monteconone accounts for the difference by noting that some of the sales CB Richard Ellis tracks may not have shown up on the tax rolls in time for the Sperry Van Ness report.
Overall, Orlando trailed behind Cleveland, Philadelphia and Cincinnati, while beating out Tampa, West Palm Beach and Jacksonville, which were among those in the top 10 buyer's markets.

Pilot program. R.W. Beck Inc. and SCS Engineers Inc. have teamed up to create a pilot program to explore the recycling potential of drywall in Orange and Seminole counties.
With the goal to help reduce the volume and odors commonly found in construction landfills, the program has received funding from the Florida Department of Environmental Protection's Innovative Recycling Grants.
Using on-site demonstrations, the program consists of the separation of drywall into two products: paper and gypsum. It has been found that gypsum produces agricultural additives for crops, such as citrus, tomatoes and peanuts.
Those in the construction community are applauding the program, and according to Kim Cochran, project manager at R.W. Beck, the pilot tests have gone well thus far and are moving to the next step.
"End markets are interested in putting recycled gypsum into their processes as a final test of the material," says Cochran.
Pilot to examine drywall reuse benefits

BY PRAKASH GANDHI

Recycling drywall may be the answer to the problem of foul odors from rotting drywall at construction and demolition debris landfills, said officials.

They are excited about a pilot recycling program in central Florida in which tons of waste drywall are separated into paper and gypsum. The gypsum is used to make cement, new drywall, and agricultural supplements for crops.

“There’s a good chance that drywall recycling will take off,” said Kim Cochran, an environmental engineer and project manager for R.W. Beck Inc., who is closely involved in drywall recycling. “We have a lot of C&D landfills that are very interested in drywall recycling because of the odor problem.”

Cochran said one of the project’s goals is testing drywall recycling technology in a series of on-site demonstrations. “So far, all of these tests have proceeded well. End markets are interested in putting recycled gypsum into their processes as a final test of the material.”

So far, drywall recycling has not “really taken off” in Florida. However, recycling is extensively done in Washington state and in Vancouver, Canada, where there’s a ban on drywall disposal.

If the drywall is not recycled, it has to be disposed of in a C&D landfill where the big problem is odor from the decomposing material. “It gives off the hydrogen sulfide gas which has a really foul odor,” she said. “But if it’s recycled, it won’t be producing this odor.”

Funding for the program is being provided by the Florida Department of Environmental Protection. An Ohio company has conducted demonstrations of the drywall recycling process at the Orange County Landfill in eastern Orange County and the 545 Landfill in Winter Garden. Those two landfills and the Seminole County Transfer Station are accepting drywall for recycling.
Pharmaceutical Science Project Nets Firm $2 Million Milestone Payment

LION bioscience AG, Heidelberg, Germany, a provider of integrated IT solutions for the life-science industry, will receive a $2 million milestone payment from Bayer AG for delivering software components for the pharmacophore informatics (Pix) project.

The project is aimed at developing an integrated cheminformatics platform to help Bayer improve its lead identification and optimization process. Pharmacophores are elements in chemical structures triggering biological activity.

The project is aimed at pinpointing the most promising leads to reduce the time and cost of developing successful drugs.

LION acted as the project manager for the deal, which first was announced in October 2000. The project is divided into milestones set for delivering specific portions of the development: data integration, analysis and visualization software, pharmacophore identification and project-tracking software.

“To adapt to new challenges, we have now signed a new modified agreement laying out a delivery schedule until June of 2004 and specifying the use of our new LION Discovery Center™ integration platform for parts of the project,” says Dr. Friedrich von Bohlen, LION bioscience's chief executive officer. “Thus Bayer will become one of our first customers for LION Discovery Center.”

Under the new terms, LION will assume additional responsibility for developing analysis and visualization software, thus increasing its share in the project.

Pilot Project to Help Find Beneficial Use for Construction Debris

A recently created program in Florida, USA's Orange and Seminole counties explores the recycling potential of drywall to reduce trash volume and foul odors in landfills. Management consulting and engineering firms R.W. Beck Inc. and SCS Engineers are overseeing the project.

Under the project, tons of wasted drywall will be separated into two products, paper and gypsum. Gypsum, commonly used to make cement and new drywall, also produces agricultural additives for crops such as citrus, tomatoes and peanuts.

“Central Florida has so much drywall from housing construction as well as commercial expansion, such as the Orange County Convention Center, that it is a good area to determine if drywall recycling can be sustained,” says Steve Cottrell, environmental specialist with the Orange County Solid Waste Division and Utilities Department.

“One of the goals for the project is testing the drywall recycling technology in a series of on-site demonstrations,” says R.W. Beck Project Manager Kim Cochran. “So far, all of these tests have proceeded well, and end markets are interested in putting recycled gypsum into their processes as a final test of the material.”
Drywall Recycling: Current Data and Developments in Orange and Seminole Counties
Kim Cochran and Chuck McLendon
R.W. Beck, Inc.
Information Exchange Meeting
November 13, 2002

Presentation Outline
- Background on drywall
- Separation of drywall from C&D debris
- Processing drywall for recycling
- Markets for recycled drywall
- Review of activities performed in Orange and Seminole Counties

Gypsum Drywall
CaSO₄·2H₂O

Environmental Impacts
- Decomposition of drywall forms H₂S in conditions such as those of a C&D debris landfill
- Represents a large fraction of C&D debris
  - Decreasing air space in landfills

How Much Waste Drywall is Out There?

Composition of C&D waste in Florida by component (by mass)
- Concrete
- Drywall
- Wood
- Misc.
- Asphalt roofing
- Metal
- Cardboard
- Plastic

3,846,000 tons
Separation

- Job Site Separation
  - Put an additional waste receptacle at the job site
  - Have a separate drywall pick-up
- Clean-up crew
- Pros:
  - Clean loads
  - High diversion
- Cons:
  - Possible increase in hauling costs
  - Possible inconvenience for residential jobs

Disposal Site Separation

- Manually or mechanically pull drywall out from the incoming loads
- Divert mostly-drywall loads from the landfill face to a staging area
- Pros:
  - Not much change to current system
- Cons:
  - Drywall in well mixed loads does not get recycled

Drywall Processing

Wood Chipper

End Product

Trommel Screen
Markets
- Portland cement production
- New drywall
- Agricultural uses
  - Soil supplement
  - Compost supplement
- Road construction

Gypsum in Portland Cement
- Gypsum comprises 6% of portland cement
- Cement comprises 10-15% of concrete
- 42,000 tons/year of gypsum are used to make 700,000 tons/year of portland cement

New Drywall
- 10 – 20% of recycled gypsum is used in production of new wallboard.
- Manufacturers are reluctant to use recycled wallboard due to potential contamination

Agricultural Uses of Gypsum
- Agricultural Soil Supplement
- Agricultural Compost Amendment

Drywall Waste Generation, Recycling, and Its Potential Demand
Innovative Recycling Grants on Gypsum Drywall Recycling

Orange and Seminole Counties
- Collection
  - Commercial projects
    - Orange County Convention Center
    - Hampton Inn
  - Advertised no tipping fee for clean loads at Orange County Landfill and the Seminole County Transfer Station
  - Diverting loads that are largely drywall at the Orange County Class III landfill
  - Working with 545 Landfill to segregate their drywall

Drywall Processing
- Process with a trommel screen
- Two processing events
  - August 15, 2002
    - Orange County
      - 60 yd³ processed material
  - November 19, 2002
    - 545 Landfill
      - 1,570 yd³ unprocessed material
- Three more events planned for the future

Orange and Seminole Counties
- Markets
  - Cement
    - FCS
    - Cemex
  - Soil amendment for peanut farmers
    - NutriSource

Orange and Seminole Counties
- Barriers
  - Low tipping fees
  - Raw gypsum is a low cost material
  - Change is difficult for many
Questions
Drywall Recycling: Developments in Orange and Seminole Counties

TAG Meeting
November 19, 2002

Separation/Collection

- Job-site separation
  - Commercial projects
    - Orange County Convention Center
    - Hampton Inn
  - Advertised no tipping fee for clean loads at Orange County Landfill and the Seminole County Transfer Station.
  - Meetings with haulers
  - Contacted general and drywall contractors in Orange and Seminole Counties
  - Overall: not enough incentive to segregate loads for the short duration of this project

Separation/Collection

- Disposal site separation:
  - Orange County Class III Landfill
    - Loads that are 70-100% drywall are being diverted to the drywall staging area
  - 545 Landfill
    - Drywall is manually and mechanically pulled out at the face of the landfill
    - Largest source of drywall for this project
  - Seminole County Transfer Station
    - Drywall loads are accepted at the transfer station then transported to the Orange County Landfill

Separation/Collection

- Agricycle
  - Successful in separating because they have a different waste collection system
  - Clean-up crews instead of roll-off containers
  - Interested in expanding processing operations to Central Florida

Drywall Generation in Orange and Seminole Counties*

- Nonresidential Construction
- Residential Construction

Construction Activity in Unincorporated Orange County*

- Residential Construction
- Nonresidential Construction

*Estimate based on research from the University of Florida and data from the U.S. Census Bureau.

*Source: Orange County Building Department
Processing

- Processing with a trommel screen
- Effective separation
- Two processing events
  - August 15, 2002
    - Orange County Landfill
    - 360 yd³ unprocessed material → 60 yd³ processed material
    - Used county trommel screen due to small amount of drywall collected
  - November 19, 2002
    - 545 Landfill
    - 1,750 yd³ unprocessed material
    - Using on-site trommel screen approved and supervised by Agricycle

Markets

- Portland Cement
  - Rinker (AKA: Florida Crushed Stone)
  - Cemex (FKA: Southdown)
- Soil amendment for peanut farmers
  - Nutri-Source

Advertisement/Promotion

- Haulers
  - Faxed notices
  - Contacted by phone
  - Face-to-face meetings
- Contractors
  - Contacted by phone
  - Job-site visits

Barriers

- Barriers
  - Low tipping fees
  - Raw gypsum is a low cost material
  - Change is difficult for many

Discussion
Drywall Recycling: Current Data and Developments in Orange and Seminole Counties
Kim Cochran and Chuck McLendon
R.W. Beck, Inc.
January 30, 2003 TAG Meeting

Background

Gypsum Drywall
CaSO_4·2H_2O

Importance of Drywall Recycling
- Decomposition of drywall forms H_2S in conditions such as those of a C&D debris landfill
  - Odor has been a significant problem for many landfills
- Represents a large fraction of C&D debris
  - Decreasing air space in landfills

How Much Waste Drywall is Out There?

Composition of C&D waste in Florida by component
(by mass)

- Concrete: 58%
- Drywall: 6%
- Wood: 13%
- Misc.: 3%
- Asphalt roofing: 1%
- Metal: 1%
- Cardboard: 7%
- Plastic: 1%

Source: University of Florida
Residential Construction Debris Composition in Florida (by mass)

- Concrete: 47%
- Drywall: 22%
- Wood: 19%
- Misc.: 3%
- Asphalt shingles: 3%
- Cardboard: 3%
- Metal: 2%
- Plastic: 1%

1,109,000 tons of waste
Source: University of Florida

Nonresidential Construction Debris Composition in Florida (by mass)

- Concrete: 58%
- Wood: 16%
- Misc.: 12%
- Drywall: 10%
- Cardboard: 2%
- Metal: 2%
- Plastic: 2%

530,000 tons of waste
Source: University of Florida

Construction Activity in Unincorporated Orange County*

<table>
<thead>
<tr>
<th>Fiscal Year</th>
<th>Residential Construction</th>
<th>Nonresidential Construction</th>
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</thead>
<tbody>
<tr>
<td>1999-2000</td>
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<td>4000</td>
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<tr>
<td>2000-2001</td>
<td>6000</td>
<td>5000</td>
</tr>
<tr>
<td>2001-2002</td>
<td>7000</td>
<td>6000</td>
</tr>
</tbody>
</table>

*Source: Orange County Building Department

Drywall Waste Generation, Recycling, and Its Potential Demand in Florida

| Source | University of Florida |

Recycling Drywall

Keys:
- Separation
- Processing
- End Markets

Separation
Separation

Job Site Separation
- Put an additional waste receptacle at the job site
  - Clean-up crew
  - Pros:
    - Clean loads
    - High diversion
  - Cons:
    - A great deal of change to the current system
    - Possible increase in hauling costs
    - Possible inconvenience for residential jobs

Disposal Site Separation
- Manually or mechanically pull drywall out from the incoming loads
- Divert mostly-drywall loads from the landfill face to a staging area
- Pros:
  - No much change to the current system
- Cons:
  - Drywall in well-mixed loads does not get recycled
  - Labor is needed to segregate the material

Drywall Processing

Trommel Screen

Markets
- Portland cement production
- New drywall manufacture
- Agriculture
  - Soil supplement
  - Compost supplement
- Road construction

Innovative Recycling Grants on Gypsum Drywall Recycling
Update: Orange and Seminole County Innovative Drywall Recycling Project

Separation/Collection

- Job-site separation
  - Commercial projects
    - Orange County Convention Center
    - Hampton Inn
  - Advertised no tipping fee for clean loads at Orange County Landfill and the Seminole County Transfer Station.
  - Meetings with haulers
  - Contacted general and drywall contractors in Orange and Seminole Counties
  - Overall: not enough incentive to segregate loads for the short duration of this project

Disposal site separation:

- Orange County Class III Landfill
  - Loads that are 75–100% drywall are being diverted to the drywall staging area
  - 80 yd³/week of drywall pulled out at the landfill face
- 545 Landfill
  - Drywall is manually and mechanically pulled out at the face of the landfill
  - 100–150 yd³
- Seminole County Transfer Station
  - Drywall loads are accepted at the transfer station then transported to the Orange County Landfill

Processing

- Processing with a trommel screen
  - Effective separation

- Four processing events
  - August 15, 2002 at the Orange County Landfill
  - November 19, 2002 at the 545 Landfill
  - January 30, 2003 at the Orange County Landfill
  - March 2003

Processing

- AgriCycle
  - Processing/recycling facility in Columbus, OH
  - Interested in expanding operations to Central Florida

- New West Gypsum
  - Processing/recycling facilities in Canada and Seattle
  - Interested in expanding operations to Florida

Orange and Seminole Counties

- Markets
  - Soil amendment for citrus and tomato farmers
    - The recycled material from this project has already been proven successful in this capacity
  - Portland Cement
  - New Drywall
Advertisement/Promotion

- Haulers
  - Faxed notices
  - Contacted by phone
  - Face-to-face meetings

- Contractors
  - Contacted by phone
  - Job-site visits
  - Contacted builders associations

Orange and Seminole Counties

- Barriers
  - Low tipping fees
  - Raw gypsum is a low cost material
  - Change is difficult for many

Discussion
Odors from C&D Debris Landfills Resulting from Gypsum Drywall

Tim Townsend
Dept of Environmental Engineering Sciences
University of Florida

C&D Debris Landfill Gas

- While C&D debris landfills may not produce the same quantity or type of “biogas” found at MSW landfills, they are “biologically active”
- The gases produced are often very foul in odor
  - $\text{H}_2\text{S}$
  - Mercaptans, Thioles

$\text{H}_2\text{S}$ Generation at C&D Landfills

- The production of hydrogen sulfide occurs when calcium sulfate is reduced to the hydrogen sulfide gas. Sulfate reducing bacteria accept electrons to reduce sulfate and hydrogen sulfide is produced

\[
\text{SO}_4^{2-} + \text{Organic Matter (e.g. Drywall paper backing)} \quad \xrightarrow{\text{Assimilatory sulfate reduction}} \quad \text{H}_2\text{S}
\]

$\text{H}_2\text{S}$ Generation at C&D Landfills

- The rate at which hydrogen sulfide is generated depends on
  - moisture
  - organic matter
  - dissolved oxygen
  - pH
  - temperature

Previous C&D Debris Landfill Gas Research

- Students
  - Sue Lee, M.E.
  - Kenton Yang, M.E.
Soil Vapor Hydrogen Sulfide

<table>
<thead>
<tr>
<th>Site</th>
<th>N</th>
<th>N+</th>
<th>Min</th>
<th>Max</th>
<th>Ave</th>
<th>Median</th>
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<td>19</td>
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<td>920</td>
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<td>0.007</td>
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<td>C</td>
<td>8</td>
<td>8</td>
<td>0.013</td>
<td>12000</td>
<td>3019</td>
<td>24.74</td>
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<tr>
<td>D</td>
<td>26</td>
<td>25</td>
<td>&lt;0.003</td>
<td>7000</td>
<td>2110</td>
<td>1800</td>
</tr>
<tr>
<td>E</td>
<td>72</td>
<td>62</td>
<td>&lt;0.003</td>
<td>2500</td>
<td>35.6</td>
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Ongoing C&D Debris Landfill Gas Research

- "C&D Waste Landfills in Florida: Assessment of True Impact and Exploration of Innovative Control Techniques"
- One Task is examining different cover soil layers for removing H₂S

Methodology

- 12 Simulated landfill columns
- Each contains drywall
- Covers evaluated
  - None (control)
  - Sand
  - Clay
  - Lime-amended sand
  - Coarse concrete
  - Fine concrete

A flow of nitrogen is passed across the top of the cover soil layers. H₂S is measured in the exit gas.
New C&D Debris Landfill Gas Research

• “Control of Odors from Construction and Demolition Debris Landfills”

  • Objective: Estimate the amount and variation of \( \text{H}_2\text{S} \) production at C&D landfills and to evaluate the impact of alternative cover materials to mitigate \( \text{H}_2\text{S} \) emissions

Approach

• Measure \( \text{H}_2\text{S} \) emission rates in the field

  • Evaluate the use of alternative cover materials for \( \text{H}_2\text{S} \) attenuation in the field
Questions

\[ \text{Flux} = \frac{C_E Q_S}{A} \]
Examining C&D Debris
Recycling Market Capacity
In Florida

Kim Cochran
R.W. Beck, Inc.

Tim Townsend, Ph.D., University of Florida
Debra Reinhart, Ph.D., University of Central Florida
Howell Heck, Ph.D., Florida Institute of Technology

SWANA’s 14th Annual Waste Reduction, Recycling, and Composting Symposium
February 25, 2003

C&D Debris

- Debris generated from the construction, renovation, or demolition of a building or other structure.
- Keys to any recycling system:
  - Separation/Collection
  - Processing
  - Resale
- Must have a viable end-market to have a feasible recycling system!

Composition of C&D waste in Florida by component
(by mass)

<table>
<thead>
<tr>
<th>Component</th>
<th>1%</th>
<th>3%</th>
<th>6%</th>
<th>7%</th>
<th>11%</th>
<th>13%</th>
<th>58%</th>
<th>3,846,000 tons</th>
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<tbody>
<tr>
<td>Concrete</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>7%</td>
<td></td>
</tr>
<tr>
<td>Drywall</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6%</td>
<td></td>
</tr>
<tr>
<td>Misc.</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>6%</td>
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<tr>
<td>Asphalt roofing</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9%</td>
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<td>Metal</td>
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<td></td>
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<td>9%</td>
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<tr>
<td>Cardboard</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>7%</td>
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<tr>
<td>Plastic</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1%</td>
<td></td>
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</table>

Concrete Recycling

<table>
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<tr>
<th>Roadstone and Coverings</th>
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<tr>
<td>20,000,000</td>
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<tr>
<td>18,000,000</td>
<td>14,000,000</td>
</tr>
<tr>
<td>16,000,000</td>
<td>12,000,000</td>
</tr>
<tr>
<td>14,000,000</td>
<td>10,000,000</td>
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<tr>
<td>12,000,000</td>
<td>8,000,000</td>
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<tr>
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<td>6,000,000</td>
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<tr>
<td>8,000,000</td>
<td>4,000,000</td>
</tr>
<tr>
<td>6,000,000</td>
<td>2,000,000</td>
</tr>
</tbody>
</table>

Concrete

- Crushed concrete can be used as a replacement for natural aggregate.

Wood

- Primary end-markets
  - Boiler Fuel
  - Mulch
    - No data on how much mulch is purchased in FL
    - Must use an approximation to determine demand.
**Wood Recycling**

- Wood from construction activities
- Wood from demolition and renovation activities
- Boiler fuel demand
- Mulch demand

### Amount Generated
- 200,000 tons
- 400,000 tons
- 600,000 tons
- 800,000 tons
- 1,000,000 tons
- 1,200,000 tons

### Amount Currently Recycled
- 0 tons
- 200,000 tons
- 400,000 tons
- 600,000 tons
- 800,000 tons
- 1,000,000 tons

### Potential Demand
- 1,200,000 tons

**Asphalt Shingles**

- Primary end-market:
  - Hot mix asphalt
  - Not heavily recycled in this manner
  - No data for demand; Approximation must be used:

Shingles demand = volume of replaced roads x density of asphalt x % shingles

**Drywall**

- Gypsum core can be a replacement for raw gypsum
- Primary end-markets:
  - New drywall
  - Agricultural amendment
  - Ingredient in portland cement

**Conclusions**

- Potential end-markets for all C&D debris generated
- Economics is the main barrier
  - Low tip fees
  - Hauling costs
Drywall Recycling: New Developments in Orange and Seminole Counties

Kim Cochran and Chuck McLendon, R.W. Beck, Inc.
Ray Lotito, SCS Engineers
Steve Cottrell, Debbie Sponsler, and Jim Becker, Orange County Government
Colleen Puglisi and Dave Gregory, Seminole County Government

Background of Drywall Recycling

Importance of Drywall Recycling

- Decomposition of drywall forms H₂S in conditions such as those of a C&D debris landfill
  - Odor has been a significant problem for many landfills

- Represents a large fraction of C&D debris
  - Decreasing air space in landfills

Innovative Recycling Grants on Gypsum Drywall Recycling

How Much Waste Drywall is Out There?
Residential Construction Debris Composition in Florida (by mass)

1.109,000 tons of waste

- Concrete: 47%
- Drywall: 22%
- Wood: 19%
- Asphalt shingles: 3%
- Cardboard: 3%
- Metal: 3%
- Plastic: 2%

Nonresidential Construction Debris Composition in Florida (by mass)

530,000 tons of waste

- Concrete: 58%
- Wood: 16%
- Misc.: 12%
- Drywall: 10%
- Metal: 2%
- Cardboard: 2%

Construction Activity in Unincorporated Orange County*

- 1999-2000
- 2000-2001
- 2001-2002

- Residential
- Nonresidential

*Source: Orange County Building Department

Recycling Drywall

Keys:
- Separation
- Processing
- Resale

Separation

- Job Site Separation
  - Put an additional waste receptacle at the job site
  - Pros:
    - Clean loads
    - High diversion
  - Cons:
    - A great deal of change to the current system
    - Possible increase in hauling costs
    - Possible inconvenience for residential jobs

- Disposal Site Separation
  - Manually or mechanically pull drywall out from the incoming loads
  - Divert mostly-drywall loads from the landfill face to a staging area
  - Pros:
    - Not much change to current system
  - Cons:
    - Drywall in well mixed loads does not get recycled
    - Labor is needed to segregate the material
Markets

- Portland cement production
- New drywall manufacture
- Agriculture
  - Soil supplement
  - Compost supplement

Drywall Waste Generation, Recycling, and Its Potential Demand in Florida

<table>
<thead>
<tr>
<th>Drywall</th>
<th>Amount Generated</th>
<th>Current Amount Recycled</th>
<th>Potential Demand</th>
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<tbody>
<tr>
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<td>0</td>
<td>0</td>
<td>700,000</td>
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<tr>
<td>New Drywall</td>
<td>200,000</td>
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<td>500,000</td>
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<tr>
<td>Agricultural Amendment</td>
<td>400,000</td>
<td>0</td>
<td>300,000</td>
</tr>
</tbody>
</table>

Separation/Collection

- Job-site separation
  - Commercial projects
    - Orange County Convention Center
    - Hampton Inn
  - Advertised no tipping fee for clean loads at Orange County Landfill and the Seminole County Transfer Station.
  - Meetings with haulers
  - Contacted general and drywall contractors in Orange and Seminole Counties
  - Overall: not enough incentive to segregate loads for the short duration of this project

Separation/Collection

- Disposal site separation:
  - Orange County Class III Landfill
    - Loads that are 75 – 100% drywall are being diverted to the drywall staging area
    - 60 yd³/week of drywall pulled out at the landfill face
  - 545 Landfill
    - Drywall is manually and mechanically pulled out at the face of the landfill
    - 100 - 150 yd³
  - Seminole County Transfer Station
    - Drywall loads are accepted at the transfer station then transported to the Orange County Landfill
Processing

• Processing with a trommel screen
  – Effective separation

• Four processing events
  – August 15, 2002 at the Orange County Landfill
  – November 19, 2002 at the 545 Landfill
  – January 30, 2003 at the Orange County Landfill
  – March 2003

• AgriCycle
  • Processing/recycling facility in Columbus, OH
  • Interested in expanding operations to Central Florida

• New West Gypsum
  • Processing/recycling facilities in Canada and Seattle
  • Interested in expanding operations to Florida

Orange and Seminole Counties

• Markets
  – Soil amendment for citrus and tomato farmers
    • The recycled material from this project has already been proven successful in this capacity!

  – Portland Cement
    • The recycled material from this project has already been proven successful in this capacity!

  – New Drywall

Orange and Seminole Counties

• Barriers
  – Low tipping fees

  – Raw gypsum is a low cost material

  – Change is difficult for many

Discussion
### Appendix D

**Orange County and Seminole County Drywall Recycling Project**

**Timeline**

<table>
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<th>Task Name</th>
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<th></th>
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<td>1</td>
<td>Re-establish contacts with contractors/haulers</td>
<td>Jun</td>
<td>Jul</td>
<td>Aug</td>
<td>Sep</td>
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<td>Nov</td>
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<td>3</td>
<td>Collect drywall</td>
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<td>Nov</td>
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<td>Nov</td>
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<td>Dec</td>
<td>Oct</td>
<td>Nov</td>
<td>Dec</td>
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<td>Dec</td>
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<td>10</td>
<td>Test material from the second processing event</td>
<td></td>
<td>Oct</td>
<td>Nov</td>
<td>Dec</td>
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<td>11</td>
<td>Third processing event</td>
<td></td>
<td></td>
<td>Oct</td>
<td>Nov</td>
<td>Dec</td>
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<tr>
<td>12</td>
<td>Test material from the third processing event</td>
<td></td>
<td></td>
<td>Oct</td>
<td>Nov</td>
<td>Dec</td>
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<td></td>
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<tr>
<td>13</td>
<td>Present project summary at SWANA conference</td>
<td></td>
<td></td>
<td>Oct</td>
<td>Nov</td>
<td>Dec</td>
<td>Jan</td>
<td>Feb</td>
<td>February 25</td>
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<td></td>
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</tbody>
</table>

**Dates:***

- August 15
- November 13
- November 19
- January 30
- February 25
Timeline

Orange County and Seminole County Drywall Recycling Project

Appendix D
Appendix E
BUSINESS PLAN FOR DRYWALL RECYCLING AT
THE 545 LANDFILL

Project Description

Gypsum wallboard has been determined to be the source of offensive odors at landfills. Because of its widespread use in new construction, gypsum wallboard is a substantial portion of the waste delivered to construction and demolition type landfills, as much as 8-10% of all waste delivered. One method to eliminate the odors caused by gypsum wallboard is to extract it from the incoming waste. Waste gypsum wallboard can be processed using equipment which is regularly used at landfills where other materials such as organic waste are recycled. With minimal effort, clean gypsum wallboard can be processed and separated into materials which are readily re-used in a variety of applications.

Extracting gypsum wallboard from mixed loads of waste is a labor and machinery intensive operation. For discussion purposes, waste gypsum wallboard comes to the landfill in three main categories: clean loads of gypsum wallboard, wallboard mixed with waste from new construction, and wallboard mixed with waste from demolition of existing structures. We have determined in the field that wallboard generated from demolition activity cannot be feasibly separated from the other waste material. On the other hand, wallboard waste coming from new construction can be extracted from the waste safely and efficiently with the proper equipment and training. Clean loads of gypsum wallboard are easily recycled with minimal equipment and manpower.

Once a sufficient amount of clean gypsum wallboard (1200-1500 tons) has been stockpiled, it can be processed at a rate of 200 tons per hour.

At the present, this project is being tested at two of Republic Services' facilities in Central Florida. The 545 Landfill extracts gypsum wallboard from the waste and stockpiles the material for periodic processing events. At the present approximately 500 tons of waste gypsum wallboard has been stockpiled for the next processing event. As we improve our efficiency, we expect to extract at least 1000 tons of wallboard each month.

At Rocket Blvd. Materials Recovery Facility, waste gypsum is also extracted from the incoming loads of construction debris. The facility manages approximately 250 tons of waste per day. As much as 35 tons of waste wallboard per week have been extracted from the trash and shipped to 545 Landfill or the Orange County Landfill.
Different processing methods will be attempted, but we have found that using the following equipment the material is processed into a product can be used for many different purposes.

**Project Requirements:**
- 2 acres, permitted for waste material processing
- Trommel Screen
- Skid Steer Loader with grapple attachment
- Wheel loader with 2 yard bucket
- 2 equipment operators; one full time, one part time.
- Minimal maintenance facilities

**Operating costs:**

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost per Hour</th>
<th>Hours per Week</th>
<th>Total Cost per Month</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skid Steer Loader with Grapple</td>
<td>$12.00</td>
<td>14</td>
<td>$727.44</td>
</tr>
<tr>
<td>Wheel Loader</td>
<td>$18.00</td>
<td>2</td>
<td>$155.88</td>
</tr>
<tr>
<td>Trommell Screen</td>
<td>$8.00</td>
<td>4</td>
<td>$138.56</td>
</tr>
<tr>
<td>Operator 1</td>
<td>$11.00</td>
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<tr>
<td>Operator 2</td>
<td>$11.00</td>
<td>4</td>
<td>$190.52</td>
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<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>$1,688.70</strong></td>
</tr>
</tbody>
</table>

During one eight hour processing event, 1600 tons can be processed for re-use. At the above costs, that gives us approximately $8.44 per ton processing cost. Tipping fees can be adjusted to encourage source separation of drywall, which would decrease processing costs. This processed material can be sold FOB at the 545 Landfill for $3-4 per ton. Additional benefits include decreased odors and increased airspace at the landfill.

**End-markets**
All end-market representatives have been very happy with the quality of the material. Only one end-market, agriculture, has stipulated that the size of the material is too large. They would like the material to be as fine as possible. The 545 Landfill can process the material for any of the end markets equally well.

**Constraints**
Fluctuations in volume of the raw material may occur. If more than 2000 tons of waste gypsum wallboard is extracted from the waste and stockpiled, then more processing events can be scheduled. There is a huge disparity in the amount of time it takes to stockpile quantities of the raw materials and the relative ease with which it is processed. As noted above, it takes approximately two days to process all the material stockpiled during one month.
Appendix F

OBSERVATIONS BY NEW WEST GYPSUM
MEMORANDUM

To: Debbie Sponsler
From: Shawn Radvanyi
Re: Central Florida Gypsum Recycling – Observations & Notes
Date: March 31, 2003

As requested, I am providing you with some observations & notes to assist in your review of the current gypsum recycling efforts in Central Florida.

Recycling Drivers:
- Environmental Impact: (a) Sebring Landfill closure as it was generating and releasing hydrogen sulfide in such high concentration the gas could be detected up to five miles away (b) Landfill leachate concerns with sulfate levels above state groundwater standards
- Societal Pressure: residents evacuation (twice) from nearby landfill due to rotten-egg odour (Sunset Landfill)
- Good Product Stewardship Initiative: Central Florida is one of the fastest growing regions in the state generating increased waste volumes
- High Volume in-state Product Sales: an approximate in-state sale of gypsum drywall is 2,000,000 tons.
- High Volume Waste: waste gypsum volume from construction & deconstruction activity is estimated at nearly 400,000 tons.

Barriers/Deterrents to Recycle:
- Very low landfilling rates ($5.25 Landfill at $5.25 per cubic yard)
- No incentive to source separate drywall waste
- No regulation or mandate to recycle gypsum waste
- More end-market exploration required
- No promotion of recycling services amongst waste generators and end-handlers
- Very low recovery rate (approximate recovery of 20 tons/week or 1000 tons/year of a potential 400,000 ton market – I say market as where New West Gypsum recycles, reclaimed gypsum is a commodity as a raw material source)

Factors to Effect & Sustain Successful Gypsum Recycling Practice:
- Need to effect a high-level (FDEP Regulation) regulated and enforced ban on landfilling of gypsum waste
- Effective recycling infrastructure development required
- Gypsum waste handling protocol development to effect source separation
- Implement weight driven disposal fees that promote source separation efforts
- Determine sustainable recycle volume capacity for dedicated end-market usage
- Utilize specialized industry professionals whose only focus is drywall recycling that can meet high-level product standards
- Educate & promote gypsum recycling and good product stewardship in ICI & Residential sectors

Plant Locations: New Westminster, B.C. • Oakville, Ontario • Fife, Washington
“GYPSUM WALLBOARD IS 100% RECYCLABLE”
www.nwgypsum.com
Regulate independent landfills & transfer stations

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