UNIVERSITY OF FLORIDA GYPSUM BOARD WASTE: AN ANALYSIS OF CURRENT TRENDS AND A PROPOSAL FOR FUTURE DIVERSION

By

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A THESIS PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
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To my Father, Mother, Sister, and Brother

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With the depletion of natural resources and the onset of climatic changes, members of the construction industry have finally acknowledged the damage the built environment has had on the natural environment and have committed to the green building movement in aspiration of reducing detrimental environmental impacts. A strategy included in the movement utilizes construction waste management plans to divert construction and demolition waste. Though many construction materials can successfully be diverted, the industry still struggles with diverting gypsum board waste. Due to the inherent difficulties during the recycling process and scarcity of facilities capable of diversion, 40 tons of gypsum board is landfilled worldwide everyday and is causing a substantial impact on the environment including creation of toxic gas, groundwater contamination, and human illness.

The University of Florida has also experienced trouble diverting the waste. Though dedicated to waste diversion, the University has yet to develop a method for diverting gypsum board waste. With over a million square feet of construction in early planning phases, the University can expect to generate a sizeable amount of gypsum board waste in the near future. In

order to reinforce their commitment to sustainable superiority, the University should develop a plan for gypsum board waste diversion.

The following study analyzes the University's current construction waste trends. A waste estimation tool capable of quantifying future waste will be developed and used jointly with previous gypsum board waste study results to determine expected future gypsum board waste. The study will also explain the University of Florida's responsibility for detrimental impacts including creation of toxic gas, groundwater contamination, and human illness.

Concluding the study is a proposal to the University of Florida for a gypsum board waste diversion program. The proposed program includes purchasing equipment suitable for the University's needs and outlines the tasks necessary for gypsum board waste diversion. The study's conclusion discusses program benefits including limiting environmental impact, physical campus improvements, monetary savings, and the reinforcement of the University's ability to lead their peers by their commitment to sustainable practices.

CHAPTER 1
INTRODUCTION

With the Earth's oil reserves rapidly depleting and the onset of climatic changes, the time has come to improve modern systems, approaches, and technologies directly impacting the environment. For example, the built environment is said to be responsible for only 8% of the gross domestic product, however is directly responsible for 40% of extracted materials, 30% of energy consumption, and 33% of the total wastestream (Kibert et al., 2002). These figures are a single illustration confirming the urgent need for modification of current trends.

Within the past two decades a movement has swept the construction industry. This movement is said to be, "the most successful environmental movement in the United States" (Kibert, 2005). Known to most in the industry as "green building" or sustainable construction, this movement has provided architects, engineers, designers, planners, general contractors, subcontractors, real estate developers, material manufacturers, and even owners with environmentally conscious strategies for constructing the built environment. Members of the movement strive to protect the environment by transforming planning, construction, and operation processes associated with constructing the built environment.

Though there are many organizations facilitating the progress of the movement, perhaps the best known organization in the United States is the United States Green Building Council, known as USGBC. The USGBC is a non-profit organization aiming to expand sustainable construction practices. The organization's mission is "to transform the way buildings and communities are designed, built, and operated, enabling an environmentally and socially responsible, healthy, and prosperous environment that improves the quality of life" (USGBC, 2008). The USGBC has over 15,000 member organizations all dedicated to improving the current practices of the design, construction, and real estate industries.

A well-known contribution of the USGBC is a certification program known as Leadership in Energy and Environmental Design (LEED). LEED is a series of rating systems that promote the creation of high performance green buildings, and are widely known as LEED Green Building Rating Systems. These systems include environmentally beneficial strategies for new construction and major renovations, existing building operation and maintenance improvements, commercial interiors, building core and shell, schools, retail, healthcare, homes, and neighborhood development. Currently the most popularly used rating system is LEED for New Construction and Major Renovations (LEED-NC).

LEED-NC is applicable to all new construction projects or major renovations to an existing building. The system is used when the owner intends on achieving green certification. In order to attain certification, a minimum number of points must be achieved. Similar to other LEED rating systems, the LEED-NC rating system classifies points into six categories: Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, Indoor Environmental Quality, and Innovation and Design Process. Each category contains a series of possible credits relating to the category that the project team can achieve during planning, construction, and building operation. Each credit is explained in detail with intent, requirements, possible options, potential technologies and strategies, and the number of points available.

Upon selecting a rating system, a project team can aim to achieve credits and points applicable to that specific project. Depending on the points achieved, the project receives a certification level. For the LEED-NC rating system there are a total of 69 possible points. Out of 69 total points a building must achieve 26-32 points to be Certified, 33-38 points to reach Silver certification, 39-51 points for Gold certification, and 52-69 points for Platinum certification.

Today there are more than 2,000 LEED certified projects and over 17,000 projects registered with the USGBC.

The University of Florida

The University of Florida is located in the city of Gainesville in Alachua County, Florida. Classes first met in a single building on the current campus in 1906 (University of Florida, 2008). Today the University has over 900 buildings spread over 2,000 acres. The University currently educates 51,000 students, with almost 10,000 of them living on campus. The University of Florida is currently one of the five largest schools in the nation and is growing at a steady pace.

Faced with the same environmental concerns previously mentioned, the University of Florida stated an initiative in 1999. With knowledge the University would continue to grow, the University had an ethical duty to utilize environmentally beneficial techniques and strategies. The University assessed their current construction practices and altered the campus building code. The revised code required the use of sustainable practices during building design and construction. Today, the building code at the University of Florida requires all new construction, at a minimum, must achieve Gold certification under the LEED-NC rating system.

The University of Florida currently has 11 LEED certified buildings, 6 additional buildings awaiting certification, and 31 total buildings registered with the USGBC. To date, the University has over one million square feet of LEED certified area and over one million square feet of space registered for certification. The University has successfully utilized a number of green building practices to limit environmental impacts resulting from the built environment. Among reducing water usage, energy usage, green house gases, pollutants, and heat island effect, the University has successfully utilized construction waste management plans to reduce the Construction and Demolition (C&D) wastestream in Alachua County.

As stated earlier, the built environment is credited with contributing 33% of the total United States wastestream. The United States Environmental Protection Agency (U.S. EPA) has estimated that 136 million tons of waste is placed into landfills across the nation annually due to construction and demolition related activities. Understanding the severe environmental impact of C&D waste, the University of Florida utilizes construction waste management plans on the majority of new construction and major renovation projects. A construction waste management plan is created in the early planning phases of a project and aims to divert as much waste as possible from the project site to a landfill. Construction waste management plans frequently incorporate a series of waste reduction ideas applicable to the project to reduce C&D waste generated. Some techniques commonly used in construction waste management plans include appropriately estimating material selection and purchasing, careful arrangement of the construction site, knowledge of recyclable materials, a management process, and proper documentation.

The USGBC considers construction waste management a crucial part of transforming the built environment and gives credit to projects utilizing plans that increase waste diversion. In fact, as part of the LEED-NC rating system, under the Materials and Resources category, there is an option to achieve points for diverting waste on a construction project. The second credit in this category is titled Construction Waste Management. Two Construction Waste Management points are possible if the project successfully diverts a percentage of the waste generated from landfills. To earn one point the project must divert 50%, for two points the waste diverted must total 75% of the total waste generated. These points are typically referred to as Materials and Resources credit 2.1 and 2.2, or MRc2.1 and 2.2. An additional point is available under the

Innovation and Design category as an exemplary performance credit if the project can successfully divert 95% of construction waste.

In order to achieve these points, the LEED-NC rating system requires the project team to “divert construction, demolition and land-clearing debris from disposal in landfills and incinerators” (USGBC, 2005). In addition, the project team must attempt to “redirect recyclable recovered resources back to the manufacturing process” and “redirect reusable materials to appropriate sites.” MRc2 also requires the development of a construction waste management plan that recognizes which construction materials will be diverted and if the waste will be commingled or sorted on site. Also detailing the credit, the USGBC includes potential strategies for accomplishing this task. Such strategies include designating areas of the jobsite for sorted or commingled waste, identifying waste haulers, and donating or salvaging materials. The USGBC also lists materials to consider recycling; “cardboard, metal, brick, acoustical tile, concrete, plastic, clean wood, glass, gypsum wallboard, carpet, and insulation.”

As stated before, the University of Florida frequently utilizes waste management plans and has achieved points for doing so on eight of the eleven certified projects. There are three additional projects awaiting certification that have also used waste diversion plans. As will be shown later, the eleven University of Florida projects utilizing waste management plans have successfully diverted over 26,000 tons of C&D waste from Alachua County landfills since 1999. The most commonly diverted construction materials include concrete and brick, metals and plastics, cardboard and paper, and wood and lumber. Even with great success diverting these materials, the University of Florida has had the least success diverting waste from a material known as gypsum board.

The University of Florida is not the only owner facing difficulties diverting gypsum board. In fact, owners, general contractors, subcontractors, waste facilities, and gypsum board manufacturers all over the world have expressed difficulty finding an efficient way of recycling or diverting gypsum board waste from landfills worldwide. The process of recycling gypsum requires the ability to separate gypsum board waste from other C&D debris, transfer the gypsum board to a recycling facility, separate the components (i.e. gypsum mixture and paper), sort contaminated boards, and remove fasteners such as screws or nails.

Though a number of facilities worldwide have attempted to recycle gypsum board waste, there are very few successful systems currently in operation. The inherent difficulties the industry faces recycling the material has resulted in over 40 tons of gypsum board ending in landfills everyday (Gypsum Recycling International, 2009). Landfilling the material results in environmental problems such as possible groundwater pollution and creation of hydrogen sulfide, a highly toxic gas. With these issues threatening environmental quality and well being of nearby humans, it is crucial for individuals generating a significant amount of gypsum board waste to take initiative and plan for the diversion of gypsum board waste. These individuals definitely include the University of Florida.

Problem Statement

Since 1999, the University of Florida has successfully diverted over 26,000 tons of C&D materials and debris from local landfills. Despite the accomplishment, the University has yet to find a suitable method for diverting gypsum board waste. In fact, gypsum board waste is the material least diverted of all C&D waste generated on University projects. Since the University aims to be as environmentally responsible as possible, and achieves this goal in most construction endeavors, it is crucial the University alters their current methods of gypsum board waste disposal to reinforce their commitment to sustainable practices. As the University of

Florida continues to expand and construct more facilities, it is critical for project teams to uphold the University's sustainable intentions and develop a successful method for diverting gypsum board waste from landfills.

Intentions and Deliverables

The following study will produce two deliverables useful to the University of Florida. First, a waste estimation tool will be developed. This tool will begin with analysis of existing University of Florida projects that have attained a certification under the LEED-NC rating system. Narrowing in on the objective, the analysis will focus specifically on University projects attaining MRc2.1 and/or 2.2 that have attempted to manage construction waste through diversion. The projects will be classified as new construction or renovation projects and will be analyzed accordingly to ensure accurate results. Using calculations developed from the University's current construction waste trends, the waste estimation tool will quantify the average waste per square foot of both new construction and renovation. The quantities determined will estimate the University of Florida's expected waste generation for future projects currently registered with the USGBC.

Utilizing results from previous gypsum board waste studies and the values determined by the waste estimation tool, next the anticipated amount of gypsum board waste expected to be generated from future projects registered with the USGBC will be determined. The detriments resulting from gypsum board waste will be discussed relative to the magnitude of the University of Florida's sizeable impact. Upon discussing the University's responsibility for toxic gas, groundwater contamination, and human illness, a plan for gypsum board waste diversion will be developed.

The second deliverable will be a proposal to the University of Florida for a gypsum board waste diversion program. The proposal will detail the actions necessary to divert the majority of the gypsum board waste the University is expected to produce throughout the duration of planned the campus expansion. The proposal will suggest the purchase of equipment suitable to the University's needs and outline the tasks to be achieved, appropriate phase to achieve each tasks, and the party responsible for achievement. The study will conclude by discussing the benefits resulting from successful implementation of the gypsum board waste diversion program. These benefits include limited environmental impact, physical campus improvements, monetary savings, and the reinforcement of the University's ability to lead their peers by their commitment to sustainable practices.

CHAPTER 2
LITERATURE REVIEW

Gypsum: The Mineral

Gypsum is a common, yet finite, mineral composed of hydrated calcium sulfate. The mineral is created from seawater, or calcium sulfate, and precipitation (Microsoft Encarta Online Encyclopedia, 2008). The mineral gypsum can be found in most clay areas. Gypsum exists in clay areas where sulfuric acid encounters limestone. Though these clay areas produce gypsum in numerous locations throughout the world, gypsum is most frequently found in volcanic regions. In these regions the sulfuric acid reacts with calcium-containing minerals to produce the mineral. Due to the extensive locations and components in the mineral, there are many varieties of gypsum. The mineral is extracted and distributed in the form of sedimentary rock.

The United States is the main miner and producer of gypsum. In a 2008 study, the United States Geological Survey (USGS) determined that the United States produced 22 million tons of gypsum valued at $165 million in 2007 alone (Olsen, 2008). The main production states in descending order are Oklahoma, Iowa, Nevada, California, Arkansas, Texas, Indiana, and Michigan. Together these states account for 77% of the total gypsum mined in the United States.

Gypsum is also produced artificially. Synthetic gypsum is created as a by-product during the production of titanium dioxide paints, desulfurization of flue gases at fossil fuel plants, and during the creation of phosphoric acid (Gypsum Association, 2009). Most commonly created during the creation of phosphoric acid, the synthetic mineral forms when tricalcium phosphate is treated with sulfuric acid. The bond results in both phosphoric acid and gypsum. The gypsum is either compacted into a mass for sale or shipped to nearby gypsum board manufacturing facilities. If the formula for the creation of phosphoric acid is slightly manipulated, the components will create a mixture of monocalcium phosphate, dicalcium phosphate, and gypsum. This mixture results in an exceptional fertilizer known as superphosphate.

Gypsum Applications

As a Building Material

The oldest known use of the mineral gypsum was by Egyptians. Egyptians used the mineral as a building material during formation of pyramids (Gypsum Association, 1999). Over the next 3,500 years, the use of gypsum remained the same. In the 1880's, Augustine Sackett was credited with developing the modern version of gypsum board known as drywall, wallboard, plasterboard, or sheet rock. Being fire resistant, capable of thermal insulation, and a proven sound barrier, the popularity of gypsum board as a building component increased.

Today, 87% of the domestic consumption of gypsum, or 42.4 million tons, is consumed by manufacturers of gypsum board or plasterboard (Olsen, 2008). In North America there are nearly 100 plants manufacturing gypsum board and the number continues to grow. By means of mining, and occasionally using artificial gypsum, these plants were expected to produce nearly 42 billion square feet of gypsum board in 2008.

Concrete is another building material frequently using gypsum as an effective component. The construction industry commonly uses gypsum as a retarder in Portland cement. Gypsum is powdered and added to Portland cement during the final phase to improve working time, setting strength, and dimensional stability (United States Gypsum, 2009). This mixture of cement can be used in numerous building components, hardscape, and repair. About 3.5 million tons of the domestic consumption of gypsum in 2007 was strictly for concrete production purposes. Combined, gypsum board, plasterboard, and cement account for 95% of the total domestic consumption of gypsum.

As a Soil Additive

Gypsum is also non-toxic, which makes it a candidate for a number of other uses. One of these uses, as stated earlier, is as fertilizer or soil additive (Gypsum Association, 1999). Incorporating small pieces of gypsum into soil result in increased saturation, workability, and protection from corrosion caused by alkalinity. Gypsum is frequently used on alfalfa, corn, cotton, wheat, and peanut crops, all which benefit from sulfate sulphur. In combination with other agricultural applications, gypsum use in soil consumes 1.8 million tons of the domestic total.

Other Applications

Other environmental applications for gypsum include the ability for the mineral to settle particles in turbid water. Gypsum is sometimes added to water to settle the particles to the bottom and is harmless to aquatic life. Gypsum is used for a variety of other uses. Gypsum can be found in medical products such as orthopedic casts and as an additive in various drugs and pills. An assortment of food and drinks utilize gypsum as a dietary source of calcium, to control clarity, or to avoid tartness. Gypsum can also be used as a color additive in cosmetics, toothpaste, and other numerous products.

Gypsum Board Fabrication

As stated earlier, the production of gypsum board and plasterboard account for 87% of the domestic consumption of gypsum. Acquiring the crude gypsum, which totals 42.4 million tons annually, is only the first step. After the mineral is mined it is transported to manufactures. These manufacturers crush the large pieces into pieces less than two inches in diameter (E-notes, 2009). Once crushed, the gypsum pieces are fed into a kiln with temperatures reaching 350 degrees Fahrenheit. The high temperature evaporates moisture naturally occurring in the mineral. For every one hundred pounds of gypsum mined, water accounts for twenty-one pounds. Therefore water accounts for only 21% of weight, but upwards of 50% of volume of the mined mineral. Once the water is removed the mineral is ground into a fine powder. This powder is known as land plaster or plaster of Paris.

Gypsum is classified into two categories: calcined and noncalcined. Calcined gypsum is used in the production of gypsum board. Calcined gypsum has an elimination of 75% of the water originally existent in the mineral (R.W. Beck and SCS Engineers, 2003). If water is added back to the mineral it becomes malleable and will then dry and harden back into gypsum rock.

The next step in the fabrication of gypsum board mixes the powdered mineral with certain helpful additives. Some manufacturers may use artificial gypsum during this process to limit the quantity of raw gypsum in the finished product. Other additives may include starch, paper pulp, and others. Starch may be added to increase the product's ability to adhere to the paper shell. Paper pulp is added to increase tensile strength in the finished product. On occasion, unexpanded vermiculite is added to create fire resistant grades of gypsum board products. Combined, these additives account for less than a half of a percent of the total gypsum mineral formula.

When the mineral mixture is satisfactory, water is added to create a slurry-like product. To this product a wax or asphalt emulsion is included to ensure moisture resistance in the gypsum board. Finally an air-entraining foaming agent is added. Using this agent ensures air will account for half of the final gypsum board product. At this point the mixture resembles a slurry-like substance. The slurry is then poured on top of recycled paper which is running below on a continuous, rolling belt. Continuing down the line and another sheet of paper tops the slurry.

This slurry, now sandwiched between two continuous sheets of recycled paper, then travels through a series of rollers, which press the boards into the proper thicknesses. Thicknesses typically range from 1/4th of an inch to one inch. As the board continues down the belt, the sides of the boards are also formed and, finally, face paper is wrapped around the board.

By this time the slurry has hardened and is ready to be sized. A knife slices the boards into standard sizes. Usually the boards are four feet in width by either eight or twelve foot lengths. These panels are then fed into a dryer oven, reaching temperatures of 500 degree Fahrenheit. During the following forty minutes, the boards continue down the conveyor belt and the oven decreases in temperature. Upon exiting the oven, the boards are bound into lifts of thirty or forty sheets and await shipment.

Gypsum Board Applications

Functions

Gypsum board is produced in a number of sizes and varieties. Common characteristics of gypsum board include fire resistance, sound attenuation, durability, and versatility. Some boards are created to be more fire resistant, moisture resistant, and/or durable than others. Most types can be finished in various colors and textures. With so many options for gypsum board, there are a number of suitable applications for the product.

Members of the construction industry are the most common users of gypsum board. The most commonly known application for gypsum board is for interior walls. Similarly, gypsum board is also used for ceilings. Certain types may be used for floors and others for backing in bathrooms and shower areas. The product can also be used for roof underlayment or erected as separation walls in multi-family structures.

Installation

During the construction process it is important to stack boards horizontally to eliminate hazard. The boards should be stored off of the floor in a dry area not prone to weather or sunlight. Prior to gypsum board application a few tests should be confirmed. If the boards will be adhered to framing, it must be confirmed that the studs are straight and at the proper angels. Also, all electric outlets should be aligned so they will be flush with the gypsum board once applied.

The application of gypsum board should begin on the ceiling, if required (National Gypsum, 2006). During the process, braces should be used to support the board once the board is aligned against the ceiling framing. Braces should be parallel to joists. The first board should be placed in a corner, butting the sides of the board into the adjacent walls. The board should be nailed or screwed to the joists. It is important to space nails and screws no more than seven inches and twelve inches apart, respectively. After application it is beneficial if the nails or screws are slightly recessed. During the process, the sheets should be staggered so no joint is longer than the length of the board. One joint across the length or width of the ceiling is likely to cause a problem in the future. All boards should be attached tight and securely.

The next step is to install the gypsum boards to the wall. Hanging the boards should begin at the top. All boards should be positioned horizontally. Placing the longest side of the sheet up, the board should abut against the ceiling. Nails or screws should be used to connect the boards to studs. The nails or screws should also be slightly recessed. To ensure adequate connection, nails should not exceed eight inches in spacing, screws not more than sixteen inches apart. After the first board, installation should continue horizontally across the ceiling, connecting boards until the end of wall is reached. After the first row is in place, the second row should begin with a board under the top row, in full contact with the boards above. There are tools available to help lift the board off the ground into the proper position and level. During installation on walls it is also important to stagger the ends of the boards to avoid future failures.

Whether applying the boards to ceilings or walls, it is common for the boards to be cut down to the appropriate size. Resizing boards provides an opportunity for errors that may result in inefficient boards. To ensure the boards are up to design standards, it is important to make all cuts with the help of a straightedge. Any imperfection in the cut will create gaps between the boards, lowering the capability of the product. The boards should be scored on one paper side with a utility knife. Then the board should be snapped, breaking it to the proper size. The paper side that was not scored will need to be cut and the new edge must be smoothed.

After installation, the board can be finished in a range of ways to provide satisfaction to the owner's preference. If installed properly the board is capable of withstanding abuse and, with minor repairs, may last as long as the building itself. A well-made, well-installed board is quite capable of enduring until renovation or demolition.

The Final Chapter in the Life of Gypsum Board

The information above explains the early phases of the life of gypsum board. To briefly summarize, the product usually starts with the mineral gypsum. The mineral is mined, crushed, heated, ground into a powder, and supplemented to create the product. Occasionally during this process, alternative or recycled gypsum is used in the mixture. There are environmental benefits if alternative or recycled gypsum is used in the process, yet this happens infrequently. Possible reasoning for recycling deterrence is discussed in following sections.

Whether or not the board is composed of alternative or recycled gypsum, once the gypsum board is produced there are many life paths the board could take. Ultimately these paths determine if the life of the material is complete or if the product continues. The following four courses are currently the most common paths for the life of gypsum board, all resulting in completion of product life. Manufacturing, demolition, renovation, manufacturing, and construction disposals are responsible for 10%, 12%, 14%, and 64%, respectively, of the total gypsum board waste generated (Marvin, 2000). These figures are from a 1990 national drywall study. Possible rationales for these statistics are explained below.

Manufacturing Disposal

Manufacturing disposal of gypsum board happens during the production process. According to the study, 18% of all gypsum board waste is disposed of during the manufacturing process and before the material is shipped out. This disposal may be due to damaged or wet boards, or boards with unacceptable quality.

Construction Disposal

Once the gypsum board arrives at a construction project, it is installed and finished, occasionally with a product containing contaminates. Once installed the life of gypsum board is unchanging until demolition or, sometimes, renovation. However, a significant amount of gypsum board is scraped during installation. In the study, 64% of the total gypsum board waste ending in a landfill was generated during the construction process. This totaled 1.7 million tons of gypsum board being transferred to landfills in the United States in a single year. As stated before, this figure was provided by a 1990 survey, and with the increase in construction in the past decade, these figures are rising as well. Currently around the world, over 40 tons of gypsum board is placed into landfills everyday (Gypsum Recycling International, 2009).

There are a few ideas that may explain the sizeable gypsum board waste generation during the construction phase. Possible setbacks include the low cost to dispose of the gypsum board and the ease of the landfilling method. Other issues may include ordering a surplus of gypsum board, shortcomings in design resulting in cutting and using excess material, high cost of labor versus cost of material, cost of separating drywall waste from other construction waste, and common practice of paying subcontractors by board as opposed to project.

Renovation Disposal

The disposal of gypsum board during renovation is credited for 14% of the total waste. The waste generated during renovation is a combination of the gypsum board previously installed that is being removed and the excess waste from the gypsum board now being installed. The compilation of waste may result from the similar issues as those discussed in the construction disposal section above and the demolition disposal section to follow.

Demolition Disposal

Demolition disposal is the waste resulting from demolition or, in a few recent cases, deconstruction. As stated earlier, demolition disposal is credited for 12% of total gypsum board waste. It is often that the gypsum board removed during demolition is transferred to a landfill with all of the demolition debris. Commingled waste usually deters people from the recycling process. It is too time consuming, and thus too expensive, to separate the material that can be recycled from the waste heading for the landfill. Another possible deterrence, even if the material is separated, is removing the hazardous gypsum board. It was common for gypsum board to be treated or finished with a material or substance that, today, is not acceptable for use in new structures, materials, or other building components. Hazardous gypsum board results from the use of lead-based paints or joint compounds containing asbestos. Separating hazardous gypsum board from non-hazardous board also requires additional labor, time, and money.

Problems Resulting from Conventional Methods of Gypsum Board Disposal

Currently, the main method for disposing of gypsum board is landfilling. As said before, construction and demolition are responsible for placing more than 40 tons of gypsum into landfills around the world everyday. Another method of gypsum board disposal, though not as common, is by incineration. These two methods of disposal result in significant environmental detriments.

Detriments Associated with Landfilling Gypsum Board

The method of transferring gypsum board waste to landfills has resulted in three main environmental detriments. The most obvious problem is the significant amount of waste taking up volume in the landfill. Once the forty-plus tons of gypsum board reaches landfill facilities everyday, the option to divert the material and continue the product life is essentially lost. Any waste terminated into a landfill ultimately lessens the value of the environment. Gypsum board is likewise accountable.

The second environmental detriment occurs when landfilled gypsum board comes in contact with water, either through precipitation or groundwater intrusion. Groundwater intrusion is not uncommon in unlined landfills. When groundwater intrusion meets gypsum board the combination results in a release of calcium sulfate, an acidic leachate. The acidic leachate is then leached into the ground and threatens the quality of groundwater and nearby drinking water supplies (Washington State Department of Ecology, 1996).

The third detriment is also a result of moisture, but in combination with an anaerobic condition. When the moist conditions reach the gypsum board and anaerobic conditions are present, sulfate-reducing bacteria begin to breakdown the chemical composition of the gypsum board into three components: water, carbon dioxide, and hydrogen sulfide gas (Marvin, 2000). Hydrogen sulfide is a colorless and highly toxic gas, recognizable by a distinctive odor resembling rotten eggs. Low quantities of the gas are harmful and higher quantities are extremely dangerous to humans. Small quantities of the gas result in irritation of the eyes, nose, throat, and may result in nausea, fatigue, shortness of breath, and chest pain. In high quantities, hydrogen sulfide can be lethal (Agri Marketing, 2009). The quantity of toxic gas released is dependent on the amount of organic matter present, the concentration of dissolved oxygen, the pH level, and the temperature. On many occasions, hydrogen sulfide has been released from the landfill in such high quantities that nearby homes must be evacuated.

Other downfalls associated with hydrogen sulfide include the gas' ability to corrode energy generators located at the landfills. Some landfills use onsite turbines to collect gases rising from the waste to generate energy. However, the turbines used are sensitive to hydrogen sulfide, which results in a corrosive effect. Not only does the gas corrode the turbines, it results in less energy production; ultimately increasing costs for maintenance and decreasing energy supply.

Detriments Associated with Incineration of Gypsum Board

Occasionally, upon disposal, gypsum board is incinerated. Though this keeps the product from crowding landfills and threatening nearby air and water quality, incinerating gypsum board results in other environmental detriments. For example, when gypsum board is burned the sulfate present in the product is transformed into sulfur dioxide gas (Washington State Department of Ecology, 1996). In high quantities, this gas reduces the capability of the incinerators to remove other acidic gases. This happens due to sulfur dioxide's ability to limit alkaline scrubbers in the incinerators. Once restricted, other acidic gases, such as hydrogen chloride, are released from the incinerators at higher emission levels.

C&D Debris

Construction and Demolition Debris (C&D) is defined by Florida Statute 403.703 as

> "Discarded materials generally considered to be not water-soluble and nonhazardous in nature, including, but not limited to, steel, glass, brick, concrete, asphalt roofing material, pipe, gypsum wallboard, and lumber, from the construction or destruction of a structure as part of a construction or demolition project or from the renovation of a structure, and includes rocks, soils, tree remains, trees, and other vegetative matter that normally results from land clearing or land development operations for a construction project, including such debris from construction of structures at a site remote from the construction or demolition project site."

The United States Environmental Protection Agency (U.S. EPA) continually monitors and analyzes the C&D wastestream. Among their research, the U.S. EPA developed a study to quantify the amount of waste generated per square foot of construction. Since the results widely varied, the projects were classified into groups depending on the type of construction. The projects were classified into two main groups: residential or non-residential, and into three sub groups: new construction, demolition, or renovation. For non-residential construction the study determined an average waste production of 3.89 pounds of waste per square foot (Franklin Associates, 1998). The study also determined non-residential demolition projects generate an average of 155 pounds of waste per square foot. Though the U.S. EPA did not calculate an average waste per square foot for non-residential renovation projects, University of Florida's Dr. Charles Kibert has performed many waste analyses and has determined non-residential renovation projects produce an average of 70 pounds of waste per square foot (Kibert, pers. comm.).

In 1998, the U.S. EPA estimated more than 136 million tons of debris was generated annually in the United States by building-related construction and demolition. This total combines residential and non-residential new construction, renovation, and demolition waste figures. The magnitude of this value indicates that over 40% of the C&D and municipal solid wastestream is a direct result of the construction industry (U.S. EPA, 2002).

Gypsum Board Present in C&D Wastestream

Gypsum board can be credited with anywhere from 4% to 76% of the total wastestream of C&D waste at any given time (R.W. Beck and SCS Engineers, 2003). USA Gypsum Inc., a gypsum board recycling company estimates 26% of the C&D wastestream to be a direct result of gypsum board (Agri Marketing, 2009). In fact, one study found that gypsum board debris is responsible for 1% of the total wastestream (Homel, 1999). The quantity of gypsum board found in the wastestream varies depending on the origination of the waste. Different types and stages of construction development generate fluctuating values.

To determine the quantities of gypsum board that result from each stage and type of development, previous studies divided the waste generators into six categories: residential construction, non-residential construction, residential renovation, non-residential renovation, residential demolition, and non-residential demolition. Multiple studies have been conducted in hopes of determining the amount of gypsum board waste in each of the six waste generating circumstances. Some results are as follows:

Residential and Non-Residential Construction Gypsum Board Debris

In 1998, the U.S. EPA determined 5% of the total waste stream was a result of residential construction waste. To determine the amount of gypsum board in this percentage, studies have been conducted on an individual home basis, by county, and even for an entire waste management district. Results from these studies credited gypsum board waste for a range of 11% to 31% of total residential construction debris (R.W. Beck and SCS Engineers, 2003). One residential construction project is estimated to generate approximately one ton of waste (The Trowel, 1997).

In the same 1998 U.S. EPA study, the non-residential construction waste totaled 3% of all C&D waste. The waste generated on a series of non-residential sites, as well as at two waste districts, was also studied. These studies found that non-residential construction waste contains a range of 7% to 11% gypsum board waste.

Residential and Non-Residential Demolition Gypsum Board Debris

The U.S. EPA study also confirmed 15% of total C&D waste is a result of residential demolition debris. One study performed by a waste authority in Iowa concluded that 15% of the total residential demolition waste was a result of gypsum board. Another study performed on a multi-family building found 17% of the wastestream to be gypsum board (R.W. Beck and SCS Engineers, 2003). Therefore it can be concluded that approximately 15% to 17% of residential demolition waste is a result of gypsum board waste.

Non-residential demolition debris accounts for 33% of all C&D debris (U.S. EPA, 1998). Non-residential demolition waste is therefore the largest generator of waste out of the six types of construction assessed. In 1998, non-residential demolition debris totaled 45.1 million tons of debris. Two studies have documented gypsum board waste in non-residential demolition debris. The first study, also performed by a waste authority in Iowa, found that gypsum board totaled 20% of the non-residential demolition wastestream (R.W. Beck and SCS Engineers, 2003). The second study, performed by a demolition contractor, examined nineteen non-residential sites in the northwest. This study concluded that 41% of the total non-residential demolition waste was a result of gypsum board waste. These two studies conclude that between 20% and 41% of all non-residential demolition waste is gypsum board waste.

Residential and Non-Residential Renovation Gypsum Board Debris

Renovation of residential projects is credited for 23% of the total C&D wastestream (U.S. EPA, 1998). In 1998, this residential renovation generated 31.9 million tons of waste (R.W. Beck and SCS Engineers, 2003). Though no specific study has examined the amount of gypsum board in residential renovation waste, a study performed by a waste authority examines the amount of gypsum in kitchen renovation. The analysis concluded that 76% of all waste in kitchen renovation is a result of gypsum board.

The final category, non-residential renovation waste, totaled 28.04 million tons of waste in 1998, and is therefore accountable for 21% of the total C&D wastestream (U.S. EPA). Of this waste, 16% was assumed to be gypsum board in a study performed by a waste authority.

Gypsum Board Recycling Programs

Observing the magnitude of environmental impact, previous attempts have been made in effort to decrease the amount of gypsum board placed into landfills. A number of gypsum board recycling programs have been initiated worldwide, however only a few have proven to be successful enough to last. The following is an analysis of successful and unsuccessful attempts at producing a gypsum board recycling program.

USA Gypsum, Inc.

USA Gypsum, Inc., located in Reinholds, Pennsylvania, began recycling gypsum board into agricultural products in 1998 (Brickner, 2008). In the company's early years, gypsum board was acquired by placing roll-off containers at the scrap source on construction projects. This method worked for the company until 2004, when there became a shortage in gypsum board and raw material. The company found problems relying on construction laborers to control separating gypsum board from both contaminated boards and other construction and demolition material. The company also faced issues with project managers who did not want their laborers wasting time separating the gypsum board. USA Gypsum needed a larger and more reliable supply of gypsum to fulfill their market demand.

Further researching the issue, USA Gypsum learned there were crews, known as drywall scrappers, which are hired by gypsum board hangers. These crews act as subcontractors and are responsible for removing excess gypsum board from jobsites. Though this seemed like a logical way to separate gypsum board waste from other waste, once the scrappers had removed the material, it was dumped at a local landfill with the rest of the construction debris. Having the gypsum board already isolated presented an opportunity for USA Gypsum to attain the scraps to fulfill their deficit.

USA Gypsum studied the costs and time associated with the new opportunity and found numerous benefits. By obtaining the gypsum board hauled by the scrappers, USA Gypsum could reduce labor costs for the hangers, obtain enough gypsum to manage necessary supply, and eliminate the gypsum board disposal costs. These benefits were all possible through development of a recycling program which would require a scrapping crew to transport a large tilt-frame truck and roll-off bins to the jobsite, collect the excess board, and transfer the gypsum board to USA Gypsum's facility. To ensure the success of the process, it was imperative the laborers worked fast and separated contaminated gypsum board.

The anticipated benefits were quickly realized. The cost decreased for contractors, subcontractors, and USA Gypsum. The contractor no longer had to provide space or money for an on-site gypsum recycling location, the drywall subcontractor no longer needed a clean-up crew, there were no longer landfill tipping fees and USA Gypsum had a steady supply of gypsum board for agricultural product production.

Currently, USA Gypsum receives and processes 20,000 tons of gypsum board scrap annually. Once acquired the material is placed into a grinding and screening system. This system is capable of separating the gypsum material from the paper material. Once separated, the gypsum material is bagged in 40 or 50 pound quantities. Typically USA Gypsum's products are used as soil additive, soil conditioners, or fertilizers. The paper captured in the screening process is also sold, usually for animal bedding or poultry litter.

USA Gypsum believes they are capable of processing up to twice the current amount of gypsum board recycled; however, the industry is still lacking a steady supply of gypsum board. USA Gypsum charges $20 per ton for contractors bringing their supply directly to the facility and sells their bagged products for approximately $3.95 per bag.

New West Gypsum Recycling

New West Gypsum Recycling, Inc. began in 1985 in Vancouver, Canada (Global Gypsum Recycling, 2002/2003). The company claims to be the world leader in recycling waste gypsum products (New West Gypsum Recycling, Inc. 2003). The company began recycling in the mid-eighties when the Greater Vancouver Regional District banned gypsum board waste from local landfills. The ban resulted in increased tipping fees to haul the waste away to a landfill out of the district. Seeing an opportunities, unethical others would lower tipping fees, collect the gypsum waste, and dispose of the waste in an illegal, unethical, and environmentally damaging way. For example, one group of individuals rented out a warehouse, collect the gypsum waste along with increased tipping fees, filled the warehouse, and left town. When the building owner repossessed the facility it was filled with waste and he was forced to pay the clean-up fees.

In hopes of providing a more beneficial method of eliminating the gypsum waste problem, Tony and Gwen McCamley, owners and operators of a construction materials waste company began experimenting with methods for recycling gypsum board. During experimentation they developed a method for minimizing the material and removing almost all paper backing. Upon development, the McCamleys founded New West Gypsum Recycling, Inc. However, the McCamleys struggled to convince manufacturers that the recycled product was suitable for reuse. In order to prove their claim, Vancouver gypsum board plant executives developed a pilot program dedicated to determining the effects of utilizing recycled gypsum in the manufacturing process for new gypsum board. Upon conclusion of the pilot, it was determined that New West Gypsum Recycling Inc.'s process was capable of efficiently handling market waste and gypsum board production. New West Gypsum Recycling, Inc. was declared a readily available source of gypsum material. Today one of McCamley's customers, a gypsum board manufacturer, explains that due to New West Gypsum Recycling, Inc.'s capabilities, their company has been successful in producing gypsum board products with over 22% recycled gypsum content with no harmful effects on quality.

Once proven to be an efficient means of recycling the material, the program assisted manufacturers, applicators, and wholesalers hoping to attain a substitute for raw gypsum or hoping to dispose of excess gypsum board waste. Today, New West Gypsum Recycling, Inc. receives waste from both pre-consumer and post-consumer parties (New West Gypsum Recycling, 2003). Once collected, the waste is cleaned by hand to ensure there is no metal, plastic, or other debris lodged in the boards. Once cleaned of debris, the waste is loaded into a feed hopper that feeds the material onto a conveyor belt. Once aboard, an electromagnet removes the remaining ferrous metal fragments. The waste then enters a processing area that separates the gypsum from the paper backing. From this point the gypsum is transported to a manufacturing facility where it is mixed with either raw or synthetic gypsum. Studies have shown success in new gypsum board products containing in excess of 25% recycled gypsum. Since 1990, the paper pulled from the waste gypsum has also been recycled and processed for a variety of applications. Figure 2.1 illustrates the recycling process. The process used by New West Gypsum Recycling, Inc. has been successful for bringing the gypsum board waste full circle; claiming 100% of the material received is recycled for reuse.

In an interview performed by Global Gypsum, Tony McCamley was questioned about the difficulties associated with recycling waste gypsum board. McCamley admits he was initially most troubled with trying to recycle wet gypsum. Since the majority of the waste is obtained at the end of the manufacturing process or from a contractor's roll off container, the gypsum board is in a moist condition. McCamley stated, "moisture content was a big challenge, which we

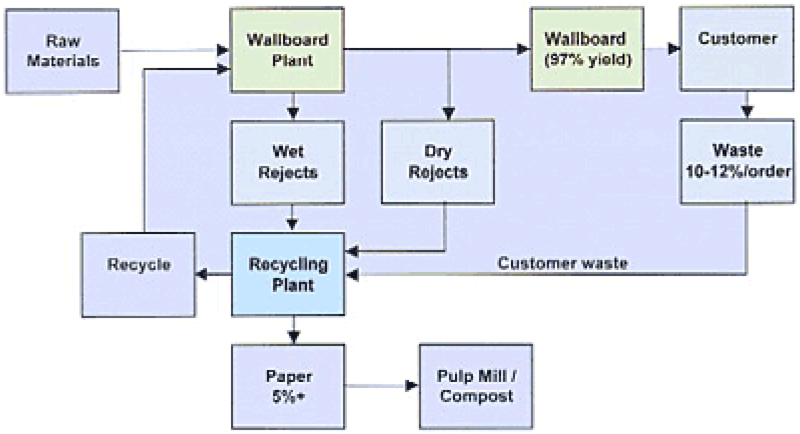

Figure 2-1. New West Gypsum Recycling, Inc. gypsum recycling process. (Source: http://www.nwgypsum.com/english/rp_01.htm. Last accessed March 2009).

solved with our patented grinding technology. The equipment has been designed to easily handle high-moisture-content scrap." McCamley added that, along with moisture content, removing the impurities from the end product are the most complicated and important steps in recycling gypsum.

Finding a process that successfully reduces the impurities and provides a manufacturer with a substitute for raw gypsum has contributed to the success of New West Gypsum Recycling, Inc. In 1998, the company was credited for recycling a pile of gypsum board the size of a football field stacked eighteen stories high totaling 133,000 tons (Homel, 1999). Today, the Vancouver plant accepts 70,000 tons of waste annually. Knowing the process is most effective in a metropolitan area with consistent flow of gypsum, the company has opened four other facilities. In addition to the British Columbia location, there is a facility in Ontario, Washington State, Bristol in the United Kingdom, and a new location in Vaujours, France. For smaller, less dense areas, New West Gypsum Recycling, Inc. has developed a self-contained portable unit capable of transporting to any site, including multi-material processing facilities and gypsum board manufacturers. The unit is capable of processing up to 25 tons of waste per hour.

All five of the New West Gypsum Recycling, Inc. locations have resulted in success. Yet the biggest downfalls are due to per-ton fees the facilities must charge to take the gypsum board scraps and the cost of transporting the gypsum board waste to the recycling facility as opposed to the landfill. New West Gypsum Recycling, Inc. knows, in order to be successful, the fees set must be competitive.

Gypsum Recycling International

Another company hoping to minimize the detrimental effects of landfilling gypsum board is Gypsum Recycling International, also known as GRI. The mother company of Gypsum Recycling Group, GRI began in Denmark in 2001. GRI's mission is clear: "It is the mission of Gypsum Recycling International to avoid landfilling of gypsum blocks and plasterboard waste, which instead can be 100% recycled into valuable raw materials for the production of new plasterboard" (Gypsum Recycling International, 2009). GRI also stated, if the company can successfully establish recycling programs, "we can assist the environment globally and save scarce natural resources, at the same time we are providing the gypsum industry with a valuable raw material at low cost."

Today GRI has locations in Denmark, Sweden, Norway, The Netherlands, Ireland, United Kingdom, and The United States. Each facility operates in a similar fashion. The first of many steps requires collection of gypsum board waste. GRI obtains waste by placing collection bins at manufacturing facilities, new construction sites, renovation and demolition sites, and at waste transfer stations. The collection bins ensure the material is protected from weather, separated from other materials, and can be easily filled and emptied by hydraulically assisted lids. The bins are sized at 40 cubic yards, which are capable of holding approximately six or seven tons of gypsum board waste.

The containers are dumped into a large collection truck and transferred to selected GRI processing facility. Usually the processing facilities are located near a gypsum board manufacturer, ultimately limiting the cost of transporting the recycled material. Once a processing facility has a large quantity of waste, a mobile recycling unit is transported to the facility. In GRI's process, the mobile recycling unit travels rather than the large quantities of waste. This also limits transportation costs by transporting the unit one time as opposed to transporting the large amount of gypsum board waste in multiple trips.

The main difference in GRI's recycling process involves the recycling unit. The recycling unit was developed in 2001 after large investments and a significant amount of research. The first recycling unit developed was a large mobile trailer capable of holding 100 tons of gypsum board waste. The second version was created in 2005 and is identified as XL Recycling Units. These units consist of two trailers, which ensure the maximum amount of gypsum board recycling while the mobile unit can still travel on standard roads.

The XL Recycling Units are not only capable of recycling unused gypsum board, the units can also recycle used gypsum board. Frequently, used gypsum board includes screws, nails, wall coverings, and other impurities. Designed with this in mind, the XL Recycling Units are capable of separating these impurities, as well as the paper backing, from the gypsum core with ease. After separating the gypsum core from the remaining materials, the XL Recycling Unit produces a recycled gypsum powder. The cost of producing the powder is low and results in a high value material for manufacturers. Other features of the compact XL Recycling Units include a fully automated system with automated sensors and controls, an almost noiseless process, an efficient separation of paper and gypsum, and very little production of dust.

GRI claims to be more successful than any other gypsum recycling process. GRI has set the world record for recycling 65% of new construction and demolition waste. GRI also claims the manufacturers receiving the recycled material can successfully use 25% recycled gypsum in place of raw material. Finally, the company claims to have saved waste owners more than 25% by recycling their gypsum board waste.

Innovative Grant Recycling Agreement in Orange and Seminole County, Florida

In the State of Florida, the need to create a recycling program for gypsum board has become increasingly obvious as the state continues to grow. In January of 2001, the Florida Department of Environmental Protection partnered with Orange and Seminole counties in an innovative grant recycling agreement (R.W. Beck and SCS Engineers, 2003). The two leading factors motivating the grant were the limited capacity of local landfills and the harmful odor problems resulting from decomposing gypsum board. The primary focus of the grant was to continue the collection and distribution of data focused on gypsum board recycling technologies and opportunities.

In the initial phase of developing the recycling program, there were four known obstacles that would be critical to overcome to ensure the success of the program. According to the study, documented by R.W. Beck and SCS Engineers, the four critical obstacles 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.”

To overcome these four obstacles, the following must happen. To overcome the first obstacle, low cost of raw materials, recycled gypsum must be available at a lower cost on a per ton basis than raw gypsum to ensure manufactures will purchase the product. The second obstacle, low disposal costs, is a result of the inexpensive and convenience of nearby landfills. This obstacle can be overcome if there is incentive to recycle, such as requiring less time and money to transport and dispose of the waste gypsum board at a recycling facility rather than a landfill. The third obstacle deals with separation of gypsum board waste from other materials and collection of the material. Overcoming this obstacle would require each jobsite to place gypsum board waste in a separate container, as opposed to the current practice of placing all waste generated into a commingled bin. This would require extra cost for another bin as well as extra cost and time to train the workers to ensure the materials are separated properly. The final obstacle focuses on processing costs and methods. Not only do the costs for processing recycled gypsum material have to be lower than the cost of raw gypsum, the recycled gypsum must also produce a product of equal quality.

Since both obstacle one and two, the low cost of raw gypsum and tipping fees, were fixed, the team focused on solving obstacle three: efficient method of separating and collecting waste gypsum board. The team formed a technical advisory group to educate all parties interested in the recycling process and get feedback from each party. The technical advisory group talked with solid waste divisions in Orange and Seminole counties, waste haulers, landfill operators, contractors, end market users, and a variety of consultants and environmental scientists. From these contacts the team formed opinions for jobsite separation of gypsum board waste versus disposal site separation.

Jobsite separation

Jobsite separation requires the gypsum board to be sorted from other waste at the construction site. Advantages of this method include an efficient means of separating gypsum board from other waste. Usually this method limits the amount of commingled waste, therefore resulting in a high quality end product due to lack of contamination. Disadvantages of this method include the requirement for contractors to educate their workers on the importance of separating the waste. This process can take time and requires a learning curve to take affect.

Another disadvantage is the increased construction disposal costs that result from having an extra storage bin to store the material. This bin also takes up valuable space on site. The final disadvantage of this method is the possibility for contamination by workers.

This method was tested in both the public and private sectors during the course of the study. For the public sector, though the selected crew was not charged collection or tipping fees and was provided with free roll off containers for gypsum board collection, the method was not successful enough due to space constraints on site and unavailability of trucks to transport the waste. As for the private sector, both the tipping fees and recycling of the gypsum waste was at no charge to the contractors and haulers. However, there were few parties interested in educating their staff and workers due to the limited duration of the program. Even less attractive, the tipping fees usually only cost one third of the total cost of servicing waste process, therefore it was not enough of an incentive for the private contractors and haulers.

Disposal site separation

The second method examined by the technical advisory group took place at the disposal site. The separation of gypsum board waste in this process can be done manually or mechanically. Since it was earlier discovered in the study that gypsum board waste is responsible for 70-80% of the C&D waste landfilled, it was assumed it would not require much effort to remove the gypsum board from the remaining waste. To test this method a local landfill, 454 Landfill, enlisted to help both the environment and themselves. The landfill only had two years of capacity remaining on the existing permit, was suffering from harmful hydrogen sulfide odors, and was applying for a permit to increase the height of the landfill by thirty feet in elevation. Recycling the gypsum board would helpful assist in all three cases.

The process for recycling gypsum board at the disposal site began when a load of C&D debris arrived at the landfill. If the load was suspected to have a large volume of gypsum board waste it was transferred to a specific location for separation by either manual or mechanical means. The main advantage of this method was easy implementation. This method did not require extra time be exhausted waiting for a learning curve or extra costs spent associated with implementing an education program. A second and less expected advantage was the ease of separating materials other than gypsum board for recycling. The waste facility found it easy to separate wood, metals, and other materials for increased profit. Disadvantages of the disposal site separating method included increased separation costs at the landfill, a new space requirement to sort the materials, and potential contamination of the gypsum board once mixed with commingled C&D debris.

Processing the gypsum board waste

During Beck's assessment of the recycling program it was said that "determining the potential end markets for a recycled material should be the first step in assessing a recycling program's feasibility." The gypsum board recycled in the Orange and Seminole County innovation grant was processed for three intended end use products: agricultural products, cement, and new gypsum board. Though there are a number of technologies useful in processing gypsum, the team felt the use of trommel screens was most fitting for the end use products.

According to the study, "the principle parts of a trommel screen include 1) a hopper at the front-end 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." Before entering the trommel, the waste is pre-processed by tossing the piles of gypsum board waste with a front-end loader to break up the large pieces. Once the gypsum board is pre-processed, the gypsum board waste is loaded into the machine where the waste enters into a tilted drum which turns to separate the gypsum core from the paper, the smaller pieces mostly consist of gypsum and fall through a screen where they are conveyed to a roll-off bin, while the larger pieces are mostly paper and are transferred down a conveyor belt to a different roll-off bin. If the larger pieces have a significant amount of gypsum still attached to the paper, the pieces can be ran through the machine again in hopes of eliminating more gypsum.

End use of the recycled gypsum

Upon exiting the trommels used, the gypsum pieces were sent to one of three locations: a farming supply broker, a cement manufacturer, or a gypsum board manufacturer. As said before it is important to know the end use for the recycled material. In this study, each of the three end uses required a different size and quality of material. When providing a farming supplier with recycled gypsum, the product did not have to be of high quality however the particle size needed to be very fine. These size specifications are necessary since pieces larger than 1/4th inch can destroy the vegetation when supplied from the spreader. Though the size specifications are of a high standard, high quality is not required. Farmers do not mind paper in the gypsum used because it will break down naturally in the soil. In fact, it is not necessary to remove any paper from the gypsum board waste when the end use is agricultural.

Some of the gypsum recycled was provided to a cement manufacturer. The company uses the gypsum as an ingredient in the cement to control setting time of the concrete. Generally five to ten percent of the cement mixture can contain gypsum. Recycled gypsum for this end use is not required to be any size, however it cannot be wet. The material provided to the manufacturer was said to be satisfactory for this percentage and was of moderate quality.

The third end use examined in the study was using the recycled gypsum as a component in new gypsum board. Recycled gypsum can successfully account for 10-20% of the total gypsum incorporated in the product. For this end use the recycled gypsum must be at a high quality with very low contamination from paper or other sources. Gypsum board manufacturers request the recycled gypsum pieces be approximately ½ inch in size. In this study, U.S. Gypsum used the recycled gypsum. The study was concluded before the success of the recycled gypsum could be analyzed.

Economics analysis of recycling gypsum

Unlike many other gypsum recycling studies, this study analyzed the economics of the process. The innovation grant studied costs associated with collection of raw material, tipping fees, transportation costs, costs associated with separating the gypsum, and possible revenue resulting from recycling gypsum board waste. Other costs may be associated with availability of certain elements of the process such as raw or alternative gypsum, gypsum board waste, recycling equipment, and end use market availability for the recycled paper. Beck discusses the importance of examining the economic value of each part of the process. "In order for drywall recycling to be sustainable, the long term economics must be favorable for every part in the value chain." The parties examined included general contractors, waste hauling companies, landfill operators, and end market users such as agricultural suppliers and cement manufacturers.

The factors assumed to be of highest important included the low cost of C&D debris tipping fees, low cost of raw gypsum and synthetic gypsum, and transportation costs. The main barrier of recycling gypsum is the low cost to landfill the waste. In Florida, average tipping fees are between $15 and $20 per ton. With such a low cost, dumping the waste usually costs less than the tipping fees at recycling facility. The second barrier is transportation costs. Since transportation costs are directly proportional to the distance of the transport, costs increase the further the waste travels. The convenience of nearby landfills requires less cost than transporting the gypsum board waste to scarce recycling facilities. Finally, the low cost of raw gypsum and alternative gypsum is the third barrier for recycling gypsum. For example, the study was conducted in an area of Florida that receives raw gypsum and synthetic gypsum for $14 to $20 per ton and -$5 to $15 per ton, respectively. The relatively inexpensive costs of the raw and synthetic materials are significantly less costly than obtaining the same quantity of recycled gypsum to the same location.

Due to low participation in the job site separation method, only the disposal site separation method could be analyzed economically. After establishing a percent recovery factor among other constants, manual separation costs, mechanical separation costs, and contaminate removal costs were assessed. The values calculated for the manual separation cost, mechanical separation cost, and contaminate removal cost are $49.19 per ton, $15.93 per processed ton, and $5.23 per processed ton, respectively. These costs are said to be typical costs of a waste facility located in an urban area that separates the gypsum board waste from a variety of materials for recycling in batches. The process of a similar facility utilizing these methods would produce 71.36 tons of gypsum and 28.64 tons of paper and “overs’ for each 100 tons of gypsum board waste recycled.

These costs were compared with the revenues associated with recycling. Revenues of the process include tipping fees and sale of the end product. Four scenarios were tested: 1) non-segregated collection and manual separation, 2) non-separated collection and mechanical separation, 3) segregated collection and 50% discounted tipping fees, and 4) segregated collection and zero tipping fee. Tables 2-1 through 2-4 depict the results. Analyzing all four tables, it is concluded that the programs using source separated collection are more economically feasible than programs with gypsum board waste mixed with other C&D debris.

Table 2-1. Economics of non-segregated collection and manual separation costs/revenues per processed ton

Activity	Orange County	545 Landfill
Separation	$ (49.19)	$ (49.19)
Processing	$ (5.23)	$ (5.23)
Paper/ “Overs” Disposal	$ (4.93)	$ (5.41)
Total Costs	*$ (59.35)*	*$ (59.83)*
Tipping Fee	$ 17.20	$ 18.88
Sale of Material	$ 5.00	$ 5.00
Total Revenue	*$ 22.20*	*$ 23.88*
Net Profits/ (Losses)	$ (37.15)	$ (35.95)

Table 2-2. Economics of non-segregated collection and mechanical separation costs/revenues per processed ton

Activity	Orange County	545 Landfill
Separation	$ (15.93)	$ (15.93)
Processing	$ (5.23)	$ (5.23)
Paper/ “Overs” Disposal	$ (4.93)	$ (5.41)
Total Costs	*$ (26.09)*	*$ (26.57)*
Tipping Fee	$ 17.20	$ 18.88
Sale of Material	$ 5.00	$ 5.00
Total Revenue	*$ 22.20*	*$ 23.88*
Net Profits/ (Losses)	$ (3.89)	$ (2.69)

Table 2-3. Economics of segregated collection and 50% discounted tipping fee costs/revenues per processed ton

Activity	Orange County	545 Landfill
Separation	$ -	$ -
Processing	$ (5.23)	$ (5.23)
Paper/ “Overs” Disposal	$ (4.93)	$ (5.41)
Total Costs	*$ (10.16)*	*$ (10.64)*
Tipping Fee	$ 8.60	$ 9.44
Sale of Material	$ 5.00	$ 5.00
Total Revenue	*$ 13.60*	*$ 14.44*
Net Profits/ (Losses)	$ 3.44	$ 3.80

Table 2-4. Economics of segregated collection and zero tipping fee costs/revenues per processed ton

Activity	Orange County	545 Landfill
Separation	$ -	$ -
Processing	$ (5.23)	$ (5.23)
Paper/ “Overs” Disposal	$ (4.93)	$ (5.41)
Total Costs	*$ (10.16)*	*$ (10.64)*
Tipping Fee	$ -	$ -
Sale of Material	$ 5.00	$ 5.00
Total Revenue	*$ 5.00*	*$ 5.00*
Net Profits/ (Losses)	$ (5.16)	$ (5.64)

CHAPTER 3
METHODOLOGY

The following text details the progression of this study. The ultimate goal of the investigation is to quantify the probable gypsum board waste the University of Florida will generate as a result of future construction projects that are currently registered with the USGBC and in early phases of development. In order to quantify this value, the progression begins with data acquisition and analysis. The applicable data is then used to create a series of spreadsheets, that when properly linked can serve as a tool for estimating future waste generation. The tool will be formatted to compute a series of calculations dependent on a common unit, area. Finally, the waste estimation tool will calculate the anticipated quantity of gypsum board waste the University will generate.

University of Florida LEED Project Documentation

As stated earlier, there are currently 900 buildings on the University of Florida campus. Of these buildings eleven have been constructed since the University took initiative ten years ago and adopted new and environmentally conscience standards. All eleven projects have achieved LEED certification with numerous projects currently awaiting certification.

Fortunately for this study, if a construction project plans to achieve a certification, the USGBC requires documentation of the approach, progress, and results to achieve each credit. With numerous LEED projects, the University of Florida documentation is plentiful and helps define typical techniques and results of the University. Useful to this study is the University's documentation delineating waste generation and diversion. However, not every project documents this information. The only projects required to document any waste generation figures are projects aiming to achieve MRc2.1 and/or 2.2.

As stated earlier, MRc2.1 and 2.2 is a LEED-NC credit aimed at diverting waste from landfills by recycling, salvaging, or donating. Of the eleven certified University of Florida projects, eight have achieved this credit and have the appropriate documentation. Of the numerous other projects awaiting certification, three projects are waiting to achieve MRc2.1 or 2.2 and are complete enough to locate documentation of waste generation and diversion. Since hopefully all future projects at the University will achieve MRc2.1 and/or 2.2, and limit environmental impacts by utilizing construction waste management plans, these eleven total projects are an accurate representation of the University's future attempts to divert waste and are appropriate for analysis. The following calculations utilize the documentation from these eleven projects to determine the University's average waste generation trends.

Analysis of University of Florida Waste Documentation

In order to quantify the expected waste the University of Florida will produce in the future, it is necessary to examine the waste generated by existing projects. The eleven University projects determined to be applicable and possessing the necessary documentation must be analyzed and evaluated. Each project will be examined and classified, when possible, based on construction type, project size, total waste generation, waste diversion, and specific material diversion. Using these categories, each of the eleven projects have been characterized.

Obtaining and Understanding Applicable Documentation

First, documentation associated with the selected projects was obtained from the University of Florida's Facilities Planning and Construction archives. Next, the documents were sorted by rating system category. The Materials and Resource documents were examined next and any document specifically relating to MRc2.1 and/or 2.2 was collected for further analysis. No matter the project, most documentation required for achieving these points is similar to any other project and is rather easy to understand.

For projects hoping to achieve MRc2.1 and/or 2.2, the project team is required to submit a sheet documenting that the project did utilize a construction waste management plan. The sheet must also provide the USGBC with details about the waste diverted. A typical sheet will record the quantity of waste diverted, the final location the waste was transported to, and the total quantity of waste generated on the project. From this information the quantity of waste diverted is divided by the quantity of total waste generated and the resulting percentage determines if the project is applicable for zero, one, or two points under MRc2, and possibly a third point in the Innovation and Design category. The following is an analysis of the information provided by the project teams intending on achieving LEED-NC MRc2.

Examining LEED Project Characteristics

Once the documentation has been collected and understood, the information can be evaluated. In order to examine the information, a spreadsheet has been created to organize the information. This begins the process of producing a waste estimation tool. The first step in constructing the tool is an initial spreadsheet used to define each project by name, area of new construction, area of renovation, and total project area. This initial set-up of the first spreadsheet is shown in Figure 3-1.

LEED-NC University of Florida LEED Point Summary	Powell Center	Vet. F ARM	Law Info. Cntr.	Library West	Harn / Cofrin Pavilion	Rinker Hall	SW Stadium Expan.	Orthopaedic Surgery	McGuire Center	NIMET Nano. Res.	Graham Cntr at Pugh
Project New Construction Area	8,565	11,900	105,500	60,000	19,240	47,270	30,600	120,000	58,000	57,867	48,617
Project Renovation Area	0	0	0	177,000	0	0	31,800	0	0	0	0
Total Project Area	**8,565**	**11,900**	**105,500**	**237,000**	**19,240**	**47,270**	**62,400**	**120,000**	**58,000**	**57,867**	**48,617**

Figure 3-1. University of Florida LEED projects utilizing Waste Management Plans.

Figure 3-1 shows the projects classified into a blue or white column. The eight projects highlighted with blue are University projects that have already received their LEED certification level. These projects are (from left to right) the Powell Structures and Materials Laboratory, Veterinarian Food and Medicine Facility (FARM), Legal Information and Phase Two Law Building, Library West Additions and Renovations, Mary Ann Harn Cofrin Pavilion, M.E. Rinker Sr. Hall, Orthopaedic Surgery and Sports Medicine Institute, and McGuire Center for Lepidoptera and Biodiversity. The remaining three projects in white columns are awaiting certification from the USGBC. From left to right, these projects are the Southwest Stadium Expansion, Nanoscience Institute for Medical and Engineering Technology Nanoscale Research Facility, and Graham Center at Pugh Hall. From this point forward, the status of a project's certification will not be discussed. For the purpose of the study, all documented projects will be treated similarly.

Examining Waste Diversion by LEED Project

The next step in analyzing the University's waste generation was to note whether the project achieved one or two points as a result of MRc2. As stated earlier, the collected MRc2 documents provide the USGBC with a total quantity of waste, quantity of diverted waste, and ultimately, percentage of waste diverted. From this percentage zero, one, or two points are awarded toward the project certification level under the Materials and Resource category. The quantities provided on the sheets were all converted into a common unit, in this case tons, and included in the spreadsheet. Figure 3-2 shows the additional information. The MRc2 credits are highlighted in yellow. The only project achieving a third point under the Innovation and Design category for exemplary performance was the Powell Center. Though this information was not necessary to this study, the achievement is noted here.

LEED-NC University of Florida LEED Point Summary		Powell Center	Vet. FARM	Law Info. Cntr.	Library West	Ham / Cofrin Pavilion	Rinker Hall	SW Stadium Expan.	Orthopaedic Surgery	McGuire Center	NIMET Nano. Res.	Graham Cntr at Pugh
	Project New Construction Area	8,565	11,900	105,500	60,000	19,240	47,270	30,600	120,000	58,000	57,867	48,617
	Project Renovation Area	0	0	0	177,000	0	0	31,800	0	0	0	0
	Total Project Area	**8,565**	**11,900**	**105,500**	**237,000**	**19,240**	**47,270**	**62,400**	**120,000**	**58,000**	**57,867**	**48,617**
Materials & Resources												
Credit 2.1	**Construction Waste Management** Divert 50% from Disposal	1	1	1	1	1	1	1	1	1	1	1
Credit 2.2	**Construction Waste Management** Divert 75% from Disposal	1		1	1	1	1	1			1	
	Total Tons Diverted	1,960.00	1,442.35	12,911.00	3,032.77	538.25	1,075.00	1,276.90	215.96	263.53	1,232.82	2,124.00
	Total Waste	2,054.00	2,322.35	14,831.00	3,822.67	678.25	1,278.00	1,663.30	362.21	508.53	1,414.60	2,704.00
	Percentage Diverted	**95.42%**	**62.11%**	**87.05%**	**79.34%**	**79.36%**	**84.12%**	**76.77%**	**59.62%**	**51.82%**	**87.15%**	**78.55%**

Figure 3-2. University of Florida LEED projects: waste diversion totals.

Examining Waste Diversion by Material

Next the LEED documents retrieved were examined in hopes of discovering which materials were most commonly diverted. Each credit sheet was examined, categorized by material, totaled, and added to the ongoing generation of the spreadsheet. The materials found in

LEED-NC University of Florida LEED Point Summary		Powell Center	Vet. FARM	Law Info. Cntr.	Library West	Ham / Cofrin Pavilion	Rinker Hall	SW Stadium Expan.	Orthopaedic Surgery	McGuire Center	NIMET Nano. Res.	Graham Cntr at Pugh
	Project New Construction Area	8,565	11,900	105,500	60,000	19,240	47,270	30,600	120,000	58,000	57,867	48,617
	Project Renovation Area	0	0	0	177,000	0	0	31,800	0	0	0	0
	Total Project Area	**8,565**	**11,900**	**105,500**	**237,000**	**19,240**	**47,270**	**62,400**	**120,000**	**58,000**	**57,867**	**48,617**
Materials & Resources												
Credit 2.1	**Construction Waste Management** Divert 50% from Disposal	1	1	1	1	1	1	1	1	1	1	1
Credit 2.2	**Construction Waste Management** Divert 75% from Disposal	1		1	1	1	1	1			1	
	Materials Diverted (in Tons)											
	Asphalt	240.00	20.00	110.00	180.00	0.00	230.00	0.00	0.00	0.00	0.00	0.00
	Cardboard and Paper	0.00	42.35	0.00	5.00	2.85	1.00	0.00	2.42	0.45	4.36	0.00
	Concrete, CMU, Brick	245.00	1,140.00	6,386.00	2,046.20	320.00	479.00	1,235.18	30.53	48.00	433.36	2,024.00
	Gypsum Wall Board	0.00	0.00	0.00	0.00	0.00	14.00	0.00	142.00	0.00	0.00	0.00
	Land and Site Debris	1,385.00	0.00	26.00	0.00	215.00	75.00	0.00	0.00	215.00	736.00	0.00
	Metals and Plastics	4.00	240.00	154.00	315.39	0.40	2.00	41.72	33.01	0.08	30.89	100.00
	Sub-base	0.00	0.00	170.00	282.50	0.00	274.00	0.00	0.00	0.00	0.00	0.00
	Wood/Lumber	0.00	0.00	0.00	97.53	0.00	0.00	0.00	8.00	0.00	28.21	0.00
	Miscellaneous/Other	86.00	0.00	6,065.00	106.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Waste	94.00	880.00	1,920.00	789.90	140.00	203.00	386.40	146.25	245.00	181.78	580.00
	Total Tons Diverted	1,960.00	1,442.35	12,911.00	3,032.77	538.25	1,075.00	1,276.90	215.96	263.53	1,232.82	2,124.00
	Total Waste	2,054.00	2,322.35	14,831.00	3,822.67	678.25	1,278.00	1,663.30	362.21	508.53	1,414.60	2,704.00
	Percentage Diverted	**95.42%**	**62.11%**	**87.05%**	**79.34%**	**79.36%**	**84.12%**	**76.77%**	**59.62%**	**51.82%**	**87.15%**	**78.55%**

Figure 3-3. University of Florida LEED projects: waste diversion totals by material.

the documentation and included in the breakdown are asphalt, cardboard and paper, concrete and CMU, gypsum board, land and site debris, metals and plastics, sub-base, wood and lumber, and miscellaneous waste. Figure 3-3 illustrates the breakdown of diverted materials. From this analysis it was discovered that the University of Florida has successfully diverted asphalt, cardboard and paper, concrete and brick, gypsum board, land and site debris, metals and plastics, sub-base, wood and lumber, and a variety of other finishes and materials.

The next step in analyzing the waste diverted required a close examination of the total amount of each material and the frequency of diverting each material. In order to examine this, the materials were totaled in their respective row and a new column was created to show the total tonnage of each material that was diverted by the University in respect to these specific projects.

LEED-NC University of Florida LEED Point Summary	Powell Center	Vet. FARM	Law Info. Cntr.	Library West	Harn / Cofrin Pavilion	Rinker Hall	SW Stadium Expan.	Orthopaedic Surgery	McGuire Center	NIMET Nano. Res.	Graham Cntr at Pugh	Total Tonnage Diverted by UF	Material Recycled on # Projects	Material Recycled on % Projects
Project New Construction Area	8,565	11,900	105,500	60,000	19,240	47,270	30,600	120,000	58,000	57,867	48,617	567,559		
Project Renovation Area	0	0	0	177,000	0	0	31,800	0	0	0	0	208,800		
Total Project Area	**8,565**	**11,900**	**105,500**	**237,000**	**19,240**	**47,270**	**62,400**	**120,000**	**58,000**	**57,867**	**48,617**	**776,359**		
Materials & Resources														
Credit 2.1 **Construction Waste Management** Divert 50% from Disposal	1	1	1	1	1	1	1	1	1	1	1			
Credit 2.2 **Construction Waste Management** Divert 75% from Disposal	1		1	1	1	1	1			1				
Materials Diverted (in Tons)														
Asphalt	240.00	20.00	110.00	180.00	0.00	230.00	0.00	0.00	0.00	0.00	0.00	780.00	5	45.45%
Cardboard and Paper	0.00	42.35	0.00	5.00	2.85	1.00	0.00	2.42	0.45	4.36	0.00	58.43	7	63.64%
Concrete, CMU, Brick	245.00	1,140.00	6,386.00	2,046.20	320.00	479.00	1,235.18	30.53	48.00	433.36	2,024.00	14,387.27	11	100.00%
Gypsum Wall Board	0.00	0.00	0.00	0.00	0.00	14.00	0.00	142.00	0.00	0.00	0.00	156.00	2	18.18%
Land and Site Debris	1,385.00	0.00	26.00	0.00	215.00	75.00	0.00	0.00	215.00	736.00	0.00	2,652.00	6	54.55%
Metals and Plastics	4.00	240.00	154.00	315.39	0.40	2.00	41.72	33.01	0.08	30.89	100.00	921.48	11	100.00%
Sub-base	0.00	0.00	170.00	282.50	0.00	274.00	0.00	0.00	0.00	0.00	0.00	726.50	3	27.27%
Wood/Lumber	0.00	0.00	0.00	97.53	0.00	0.00	0.00	8.00	0.00	28.21	0.00	133.74	3	27.27%
Miscellaneous/Other	86.00	0.00	6,065.00	106.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6,257.15	2	18.18%
Waste	94.00	880.00	1,920.00	789.90	140.00	203.00	386.40	146.25	245.00	181.78	580.00	5,566.33		
Total Tons Diverted	1,960.00	1,442.35	12,911.00	3,032.77	538.25	1,075.00	1,276.90	215.96	263.53	1,232.82	2,124.00	26,072.57		
Total Waste	2,054.00	2,322.35	14,831.00	3,822.67	678.25	1,278.00	1,663.30	362.21	508.53	1,414.60	2,704.00	31,638.91		
Percentage Diverted	**95.42%**	**62.11%**	**87.05%**	**79.34%**	**79.36%**	**84.12%**	**76.77%**	**59.62%**	**51.82%**	**87.15%**	**78.55%**	**82.41%**		
Total Waste (in lbs) per Square Foot	**479.6264**	**390.3109**	**281.1564**	**32.25882**	**70.504**	**54.07235**	**53.3109**	**6.03688**	**17.5353**	**48.89142**	**111.2368**	**81.505864**		

Figure 3-4. University of Florida LEED projects: material waste diversion total quantity and frequency.

Figure 3-4 illustrates these values. The total diversion column is highlighted on the spreadsheet in green. Next, the number of projects that successfully diverted each material was counted and totaled quantifying the frequency of diversion for each material. In the final column, the frequency was divided by the total number of projects, in this case, eleven. This solution of this computation is the percentage of University of Florida projects that divert the corresponding material. The frequencies and percentages are included in the spreadsheet in two additional columns. These totals are also shown in Figure 3-4.

Development of Waste Estimation Tool Capable of Estimating the Future Wastestream

Analyzing the data collected from existing University projects allows easier computation to estimate the University's future waste generation. In order to achieve this estimate, data detailing the waste produced by University construction must be formatted into a unit that is compatible with future projects. A commonly used construction unit, which is also applicable in this study, is the square foot. Found in the data collected is the total square footage for each project and all projects registered with the USGBC must also declare an expected square footage. Therefore, by breaking the University waste during construction into an average square foot unit, the waste of future projects can be estimated.

However there is still consideration to be taken. While researching the eleven projects, it was discovered that three of the projects had undergone a major demolition before construction began. The demolition involved with these projects was a result of destructing an existing structure entirely and, therefore, not classified as renovation. These three projects were the Powell Structures and Materials Laboratory, the Veterinarian Food and Medicine Facility (FARM), and the Legal Information and Phase Two Law Building. In order to ensure the waste estimating tool would be as accurate as possible, the amount of waste resulting from demolition should be quantified and separated from the waste generated from new construction. However, there is no documentation available that could specify the total amount of waste resulting from demolition. In order to ensure the waste resulting from demolition does not affect the accuracy of the waste estimating tool, the three projects with major demolition should not be included when averaging the waste generated per square foot.

Similar to the major demolition projects, there are projects that underwent renovation. Renovation in this study is characterized by retrofitting existing structures that will ultimately remain in conjunction with the new construction. Of the eleven projects, two projects required renovation: the Library West and the Stadium Expansion. In order to be sure the quantity of predicted waste reflects the best possible estimate, the renovated projects will be calculated secondary to the new construction projects. In fact, after calculating the average waste per square foot generated for new construction, the average will be used as a constant for computing the average waste per square foot resulting from University renovation. The methods used to compute these averages are further explained in the following sections.

Waste Per Square Foot of Construction

First, to calculate the University's average waste per square foot during new construction projects, only data from the six applicable new construction projects can be averaged. To calculate this average a new spreadsheet was created. Only the data from the following projects will be used: the Mary Ann Harn Cofrin Pavilion, M.E. Rinker Sr. Hall, Orthopaedic Surgery and Sports Medicine Institute, McGuire Center for Lepidoptera and Biodiversity, Nanoscience Institute for Medical and Engineering Technology Nanoscale Research Facility, and Graham Center at Pugh Hall.

The calculations required to compute average waste per square foot of new construction are performed on a second spreadsheet illustrated in Figure 3-5. In order to find the average waste per square foot generated during new construction, it is necessary to first find the waste generated per square foot for each project. To find this number, the total waste generated on each project is divided by the square footage of new construction on that specific project. As may have been noticed, the quantity of waste generated on each project has been altered since Figure 3-4. These new quantities express actual waste generated as a result of new construction, and do not include waste generated from land clearing, site clearly, parking lot demolition, or site stabilization. After dividing the generated waste by the new construction square footage, the resulting numbers are expressed in total tons of waste per square foot of new construction and are and highlighted in light blue in Figure 3-5. These values are also converted into pounds of waste per square foot of new construction and highlighted in dark blue. This conversion is simply a more comprehensible option to view the range of results.

Finally, all of the values must be translated into one value that can be used as a constant. In order to determine the single value constant, the quantities found for waste generated per square foot of construction on each of the nine projects must be averaged into one value. The average is calculated by first totaling the nine waste per square foot values. The resulting sum is then divided by the quantity of projects, in this case, six. The result is the average number of tons of waste generated per square foot of new construction projects attaining MRc2.1 and/or 2.2 credits at the University of Florida. Figure 3-5 shows the spreadsheet generated to find tons of construction waste per square foot of new construction. These values are highlighted in orange and will now be referred to as NC Constant. The NC Constant will be helpful in determining two other values. First, the NC Constant will be applied to a formula to determine the average amount of waste previously generated during renovation at the University. Second, the value will be applied to a different formula to determine the University's construction and renovation waste expected to result from future projects currently registered with the USGBC.

LEED-NC

University of Florida
LEED Waste Summary New Construction

	Harn / Cofrin Pavilion	Rinker Hall	Orthopaedic Surgery	McGuire Center	NIMET Nano. Res.	Graham Cntr at Pugh	New Construction Average (NC Constant)	
Project New Construction Area	19,240	47,270	120,000	58,000	57,867	48,617		
Project Renovation Area	0	0	0	0	0	0		
Total Project Area	19,240	47,270	120,000	58,000	57,867	48,617		
Total Waste in Tons	143.25	220.00	362.21	245.53	267.60	1.35		
Total Tons Waste per Square Foot	0.00745	0.004654	0.00302	0.00423	0.004624	2.78E-05	0.0040	Tons Waste/SF
Total Pounds Waste per Square Foot	14.8906	9.308229	6.03688	8.46638	9.248795	0.055618	8.0011	Pounds Waste/SF

Figure 3-5. University of Florida LEED projects: new construction average waste per square foot.

Waste Per Square Foot of Renovation

The collected documentation from the University of Florida's LEED projects attaining MRc2.1 and/or 2.2 does not distinguish between waste generated as a result of new construction and waste generated as a result of minor alterations or renovations required by the project. Since the quantity of waste is only documented for the total project, it is necessary to develop a method to determine waste resulting solely from new construction and waste resulting solely from renovation.

Since the NC Constant, an average waste per square foot has already been determined for new construction projects, this value can be used to determine the waste resulting from renovation on University projects with both types of construction. As stated earlier, projects classified as renovation in this study did not demolish an existing structure completely, these projects retrofitted an existing structure that remained jointly with the new construction project. The two renovation projects excluded from the second spreadsheet were the Library West and the Stadium Expansion. A third spreadsheet can be developed to analyze these two projects as part of the waste estimation tool.

The first step in creating the third spreadsheet is to declare the square foot areas associated with new construction and renovation for both projects. These square footages are also summed into total project area. Next, using the data from the collected project waste documentation, the total amount of waste generated on each project is also identified on the spreadsheet. Figure 3-6 shows the initial generation of the third spreadsheet.

LEED-NC

University of Florida
LEED Waste Summary NC and Reno

	Library West	SW Stadium Expan.
Project New Construction Area	60,000	30,600
Project Renovation Area	177,000	31,800
Total Project Area	**237,000**	**62,400**
Total Waste in Tons	3,822.67	1,663.30

Figure 3-6. University of Florida LEED projects: renovation projects

The next step is to calculate the waste generated from new construction on each project. In order to do this, the NC Constant that was determined in the second spreadsheet is also located on the third spreadsheet, and is again highlighted in orange. To calculate the assumed waste from new construction, the NC Constant is multiplied by the area of new construction. The NC Constant is measured in tons of waste per square foot of new construction and the area of new construction is provided in square feet. Therefore, the resulting value is the assumed waste generated from new construction on each project and is expressed in tons. A rows is added to the third spreadsheet for this information and they are show in Figure 3-7.

LEED-NC

University of Florida
LEED Waste Summary NC and Reno

	Library West	SW Stadium Expan.
Project New Construction Area	60,000	30,600
Project Renovation Area	177,000	31,800
Total Project Area	**237,000**	**62,400**
Total Waste in Tons	3,822.67	1,663.30
Total Tons of Waste per Square Foot (NC Constant)	0.0040	0.0040
Calculated Tonnage of New Construction Waste (New Construction Area X NC Constant)	240.03	122.42

Figure 3-7. University of Florida LEED projects: assumed new construction waste on renovation projects.

Once values are estimated for the new construction waste produced on each renovation project, the remaining waste is assumed to be a result of renovation. To calculate the assumed quantity of waste from renovation, the tonnage of new construction waste is subtracted from the total waste generated on each project. These values are also documented in a new row on the third spreadsheet of the waste estimating tool. Next, the renovation waste is divided by the square footage of the renovation area of each project. As calculated before, dividing the total quantity of waste by the area provides the value of waste per square foot for the project. The results of this calculation are in the unit tons of waste per square foot of renovated area. Similar to the new construction waste calculation, the tonnages can be converted into pounds. These new values are calculated on the third spreadsheet. The tonnages and pounds of waste per square foot are shown in Figure 3-8 and highlighted in purple and gray, respectively.

Finally, to calculate the “Reno Constant” the renovation waste per square foot values must be averaged into one value to be used in estimating future project waste generation. The values from each project are summed and then divided by the number of projects, in this case two. The constant is highlighted in yellow in Figure 3-8.

LEED-NC

University of Florida
LEED Waste Summary NC and Reno

	Library West	SW Stadium Expan.	Renovation Average (Reno Constant)
Project New Construction Area	60,000	30,600	
Project Renovation Area	177,000	31,800	
Total Project Area	**237,000**	**62,400**	
Total Waste in Tons	3,822.67	1,663.30	
Total Tons of Waste per Square Foot (NC Constant)	0.0040	0.0040	
Calculated Tonnage of New Construction Waste (New Construction Area X NC Constant)	240.03	122.42	
Remaining Waste Assumed to be Renovation Waste (Total Waste - Calculated New Construction Waste)	3,582.64	1,540.88	
Assumed Renovation Tons Waste per Square Foot of Renovation Area (Assumed Renovation Waste / Square Feet of Renovation Area)	**0.0202**	**0.0485**	**0.0343 Tons Waste/SF**
Assumed Renovation Pounds Waste per Square Foot of Renovation Area	**40.4818**	**96.9109**	**68.6963 Pounds Waste/SF**

Figure 3-8. University of Florida LEED projects: renovation waste generated per square foot

Final Development of Waste Estimation Tool and Quantification of University of Florida's Future Waste Generation

Once the NC Constant and Reno Constant, the new construction and renovation constants respectively, for waste generation have been established, the values can be used to estimate future waste generation. In order to do this a fourth and final spreadsheet is developed as part of the waste estimation tool. This spreadsheet outlines future projects that are currently registered with the USGBC. At this point there are sixteen projects in the early planning phases or early construction phases. Next each of the projects is listed horizontally on the fourth spreadsheet. Specifics for each project are then detailed. These details include the new construction square footage, renovation square footage, and totals of each of the sixteen projects. The waste constants are also placed on the spreadsheet for ease of calculation. Figure 3-9 shows the set up of the fourth spreadsheet with the NC Constant and Reno Constant placed at the top and highlighted in orange and yellow respectively.

Tons of Waste per Square Foot of New Construction (NC Constant)	0.0040 Tons Waste/SF
Tons Waste per Square Foot of Renovation Area (Reno Constant)	0.0343 Tons Waste/SF

LEED-NC

University of Florida Future LEED Projects Anticipated Waste Summary	Steinbrenner Band	IFAS	Pathogens	Biomedical Science	SW Parking Garage	Hough Graduate Students Hall	Levin Advocacy Center	Lacrosse Facility	Stadium 3rd and 4th Floor	Harn/Asian Art Wing	Vet. Ed. & Clinical Research	Golf Course Clubhouse	Autopsy Med. Science	Student Health Care	East Campus Office	SW Rec Center Expan
Future Project New Construction Square Footage	18082	5560	90000	163000	300000	53700	14956	21975	33500	22000	93000	7200	0	64000	100000	37000
Future Project Renovation Square Footage	0	0	0	0	0	0	0	0	0	0	0	2400	1245	0	0	6500
Future Project Total Square Footage	**18082**	**5560**	**90000**	**163000**	**300000**	**53700**	**14956**	**21975**	**33500**	**22000**	**93000**	**9600**	**1245**	**64000**	**100000**	**43500**

Figure 3-9. University of Florida registered LEED projects.

The next step in producing the waste estimation tool is to multiply the square footages by the appropriate constant. To do this, first, the expected new construction square footage for each future project is multiplied by the NC Constant. Since the NC constant is measured in tons of waste per square foot of new construction and the expected new construction is quantified in square feet, the result of multiplying the two figures is expressed in tons. These values were then placed in a row below the corresponding project and highlighted in blue.

Tons of Waste per Square Foot of New Construction (NC Constant)	0.0040 Tons Waste/SF
Tons Waste per Square Foot of Renovation Area (Reno Constant)	0.0343 Tons Waste/SF

LEED-NC

University of Florida Future LEED Projects Anticipated Waste Summary	Steinbrenner Band	IFAS	Pathogens	Biomedical Science	SW Parking Garage	Hough Graduate Students Hall	Levin Advocacy Center	Lacrosse Facility	Stadium 3rd and 4th Floor	Harn/Asian Art Wing	Vet. Ed. & Clinical Research	Golf Course Clubhouse	Autopsy Med. Science	Student Health Care	East Campus Office	SW Rec Center Expan
Future Project New Construction Square Footage	18082	5560	90000	163000	300000	53700	14956	21975	33500	22000	93000	7200	0	64000	100000	37000
Future Project Renovation Square Footage	0	0	0	0	0	0	0	0	0	0	0	2400	1245	0	0	6500
Future Project Total Square Footage	**18082**	**5560**	**90000**	**163000**	**300000**	**53700**	**14956**	**21975**	**33500**	**22000**	**93000**	**9600**	**1245**	**64000**	**100000**	**43500**
Estimated Tons of Waste from NC (New Construction Area X NC Constant)	72.3379	22.243	360.049	652.089	1200.16	214.829	59.8322	87.912	134.018	88.012	372.051	28.8039	0	256.035	400.055	148.02
Estimated Tons of Waste from Reno (Renovation Area X Reno Constant)	0	0	0	0	0	0	0	0	0	0	0	82.4356	42.7635	0	0	223.263
Estimated Tons of Waste from Construction	**72.3379**	**22.243**	**360.049**	**652.089**	**1200.16**	**214.829**	**59.8322**	**87.912**	**134.018**	**88.012**	**372.051**	**111.24**	**42.7635**	**256.035**	**400.055**	**371.283**

Figure 3-10. University of Florida registered LEED projects: anticipated waste per project.

Next, the expected renovation square footage for each future project is multiplied by the Reno Constant, which is measured in tons of waste per square foot of renovation. Again, the resulting quantity will be provided in tons. These values are highlighted in purple in an additional row below the new construction results. Finally, the expected waste for new construction and renovation for each project are summed in a corresponding row and highlighted in dark gray. All results of the fourth spreadsheet are show in Figure 3-10.

The final step in creating the waste estimation tool is to total the values found for each project. These totals include total square footages for new construction, renovation, and total project square footage, as well as expected waste totals from new construction, renovation, and combined waste. These values are summed in a new column to the far right of all spreadsheet calculations and shown in Figure 3-11. The waste resulting from new construction of projects is highlighted in blue, waste resulting from future renovation projects is highlighted in purple, and the sum of the two is in dark gray in Figure 3-11.

LEED-NC

University of Florida
Future LEED Projects
Anticipated Waste Summary

	Steinbrenner Band	IFAS	Pathogens	Biomedical Science	SW Parking Garage	Hough Graduate Students Hall	Levin Advocacy Center	Lacrosse Facility	Stadium 3rd and 4th Floor	Harn/Asian Art Wing	Vet. Ed. & Clinical Research	Golf Course Clubhouse	Autopsy Med. Science	Student Health Care	East Campus Office	SW Rec Center Expan		
Future Project New Construction Square Footage	#	#	#	#	#	#	#	#	#	#	#	#	0	#	#	#	Total NC Square Footage	1,023,973
Future Project Renovation Square Footage	0	0	0	0	0	0	0	0	0	0	0	#	#	0	0	#	Total Reno Square Footage	10,145
Future Project Total Square Footage	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	**Total Future Project Square Footage**	**1,034,118**
Estimated Tons of Waste from NC (New Construction Area X NC Constant)	#	#	#	#	#	#	#	#	#	#	#	#	0	#	#	#	**Total Tons of Waste from NC**	**4,096.45**
Estimated Tons of Waste from Reno (Renovation Area X Reno Constant)	0	0	0	0	0	0	0	0	0	0	0	#	#	0	0	#	**Total Tons of Waste from Reno**	**348.46**
Estimated Tons of Waste from Construction	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	**Total Tons of Construction Waste**	**4,444.91**

Figure 3-11. University of Florida registered LEED projects: anticipated waste for all construction.

Finishing the fourth and final spreadsheet, the waste calculating tool has been completed. The tool began with an initial spreadsheet capable of analyzing all University of Florida LEED-NC projects achieving the MRC2.1 or 2.2 credits. The projects were examined based on total waste generated, total waste diverted, percentage of waste diverted, and materials contributing to waste diversion. After analyzing the first spreadsheet, a second was created.

The second spreadsheet focused solely on new construction projects. There were six projects applicable for new construction analysis. These projects required no demolition or renovation. After inputting the project characteristics, the waste per square foot was determined for each project. Next, the waste quantities from all six projects were averaged and a NC Constant was determined. This constant was helpful in developing the third and fourth spreadsheets.

The third spreadsheet examined the two University renovation projects. Multiplying the NC Constant by the project square footage of new construction, the waste resulting from new construction was determined. This waste was subtracted from the total waste generated on the project and the remaining waste was credited to renovation. Next, the renovation waste was divided by the renovation square footage for each project. The two results were averaged into the Reno Constant, measured in tons of waste per square foot of renovated area.

Finally, these two constants were utilized on the fourth and final spreadsheet. The fourth spreadsheet listed sixteen future projects registered with the USGBC, the area of new construction, and renovation area for each project. Finally the square footages for new construction and renovation were multiplied by the NC Constant and Reno Constant respectively and the results were totaled. The total value, expressed in tons, details the expected waste the University will generate during new construction and renovation of the sixteen future projects currently registered with the USGBC. With little manipulation, the waste calculator tool can be used in association with waste trends of other projects to predict future waste generation.

CHAPTER 4
RESULTS

The findings discussed in this chapter were calculated by the waste calculator generated in the previous chapter. Results were computed from facts and data collected directly from the University of Florida Facilities Planning and Construction archives. The results discovered from each of the four spreadsheets are discussed in consecutive order followed by a gypsum board waste analysis.

University of Florida Material Diversion Analysis

The first spreadsheet during generation of the waste calculator, outlined the main characteristics of all projects at the University of Florida attaining LEED-NC MRc2.1 and/or 2.2 Figure 4-1 is a closer look at the earlier examined Figure 3-4. Considering only the material and diversion percentage, it is evident which materials the University successfully diverts and for which materials the University has not yet found a suitable diversion method. Analyzing the column illustrating the percentages of diversion for each material, it is clear to see that the University has a successful diversion method for concrete and brick, metals and plastics, and even cardboard and paper. However, it is the most obvious that the University has yet to find a suitable approach to diverting gypsum board.

In fact thus far, gypsum board has only been recycled on two University of Florida projects, or 18.18% of the projects utilizing construction waste management plans. No other specific material is recycled as infrequently as gypsum board. In fact, the only category with a percentage equally as low is the “miscellaneous/other” category, which is most likely a result of the infrequent use of the materials classified into that group. Observing the University’s infrequent gypsum board waste diversion, understanding the large quantities of waste associated with construction, and being aware of the detrimental effects gypsum board waste has on the environment, it becomes increasingly obvious that the University of Florida needs a solution for gypsum board diversion.

LEED-NC

Materials Diverted (in Tons)	Total Tonnage Diverted by UF	Material Recycled on # Projects	Material Recycled on % Projects
Asphalt	780.00	5	45.45%
Cardboard and Paper	58.43	7	63.64%
Concrete, CMU, Brick	14,387.27	11	100.00%
Gypsum Wall Board	156.00	2	18.18%
Land and Site Debris	2,652.00	6	54.55%
Metals and Plastics	921.48	11	100.00%
Sub-base	726.50	3	27.27%
Wood/Lumber	133.74	3	27.27%
Miscellaneous/Other	6,257.15	2	18.18%
Waste	5,566.33		
Total Tons Diverted	26,072.57		
Total Waste	31,638.91		
Percentage Diverted	**82.41%**		

Figure 4-1. Waste diversion total quantity and frequency examined by material.

University of Florida Waste Per Square Foot of New Construction

The second spreadsheet created during generation of the waste calculator averaged the waste generated per square foot of new construction. The sheet listed six projects at the University that were strictly new construction, the square footage of each new construction project, the quantity of waste generated in tons for each project, and finally calculated the waste per square foot for each project. After averaging these values, the resulting mean is 0.0040 tons, or 8.0011 pounds, of construction waste per square foot of new construction. These values were highlighted in orange on the second spreadsheet, which has been reduced to just the resulting constant and is illustrated in Figure 4-2.

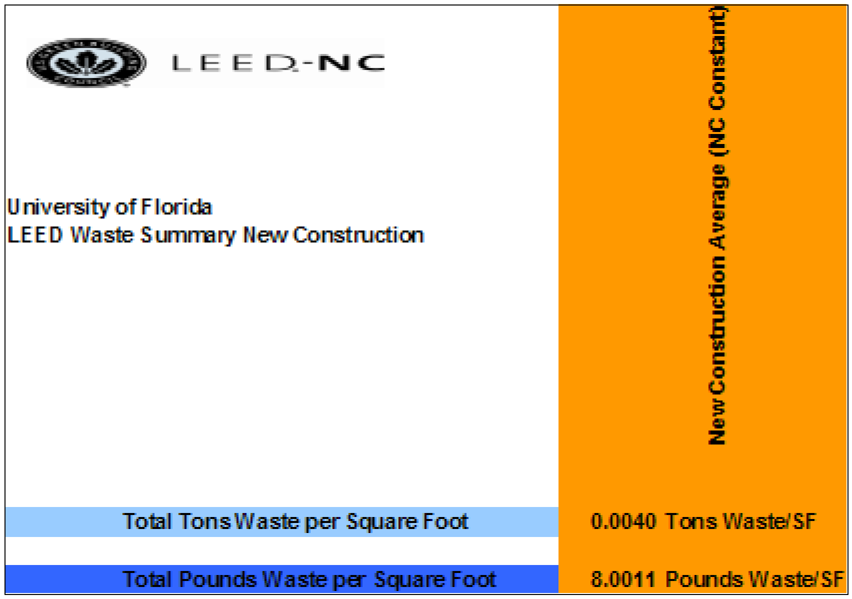

Figure 4-2. University of Florida: tons of waste generated per square foot of new construction.

University of Florida Tons of Waste per Square Foot of Renovation

The third spreadsheet attempted to quantify the waste generated at the University of Florida on renovation projects. This sheet utilized the NC Constant found in spreadsheet two. The spreadsheet listed the two projects found to be renovation projects, the project's new

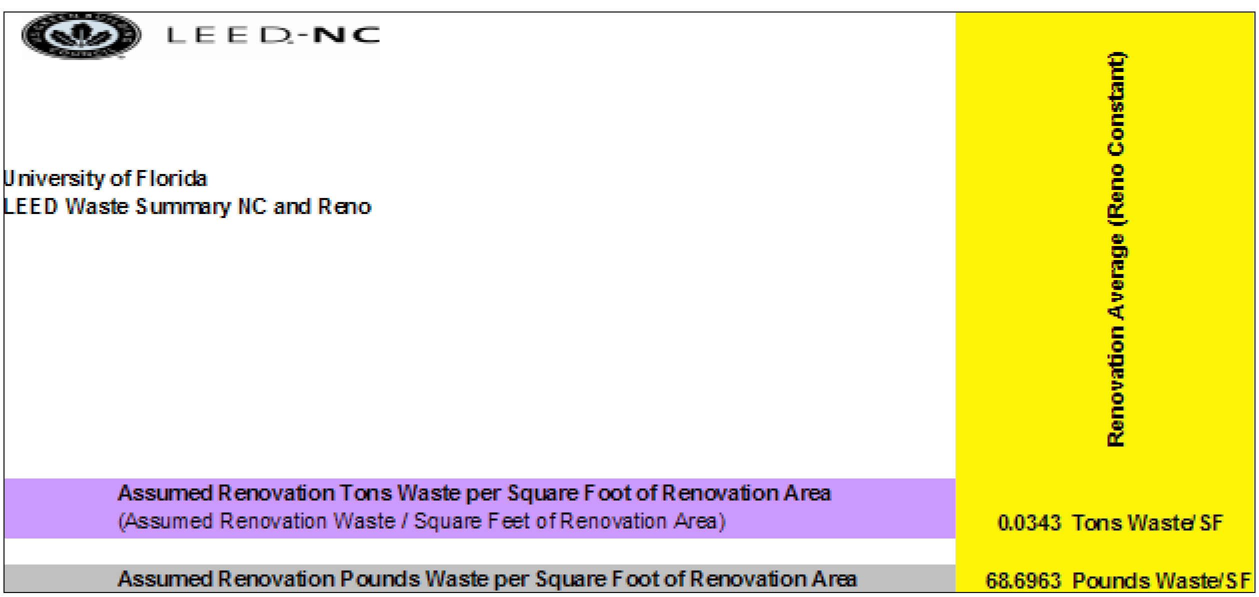

Figure 4-3. University of Florida: tons of waste generated per square foot of renovation.

construction square footage, the renovation square footage, and the NC Constant. Showing only the results of the third spreadsheet, Figure 4-3 illustrates that 0.0343 tons, or 68.6963 pounds, of construction waste is generated per square foot of renovation on University projects. The value, which is highlighted in yellow, is known as the Reno Constant. This number will be helpful in determining the amount of waste generated on future projects intending to renovate an existing structure.

University of Florida Total Waste Generated from Future New Construction and Renovation

The fourth and final spreadsheet of the waste estimating tool analyzes sixteen future projects. All sixteen projects are currently registered with the USGBC. These projects were placed on the fourth spreadsheet and characterized by square footage of new construction and/or square footage of renovation. Once listed on the spreadsheet the square footages were multiplied by the applicable constant, either NC Constant or Reno Constant. Once the expected waste for each future project was estimated, the results were totaled. Utilizing the waste calculator, the expected future waste resulting from new construction will total 4,096.45 tons. With similar calculation, the waste resulting from future renovation projects is estimated at 348.46 tons. Next these values are summed to determine the total waste expected to be generated on future University projects already registered with the USGBC. These values combined will result in an estimated 4,444.91 tons of waste. This value is highlighted in dark gray in Figure 4-4. Figure 4-4 is the final section of the fourth spreadsheet of the waste estimation tool previously shown in Figure 3-11. The expected new construction waste and renovation waste are highlighted in blue and purple respectively.

LEED-NC

University of Florida
Future LEED Projects
Anticipated Waste Summary

Total NC Square Footage	1,023,973
Total Reno Square Footage	10,145
Total Future Project Square Footage	**1,034,118**
Total Tons of Waste from NC	**4,096.45**
Total Tons of Waste from Reno	**348.46**
Total Tons of Construction Waste	**4,444.91**

Figure 4-4. University of Florida: expected waste generated from future LEED projects

CHAPTER 5
ANALYSIS

The previous chapter developed a tool capable of estimating the quantity of waste the University of Florida can expect to generate as a result of sixteen future projects registered with the USGBC. As explained earlier, new construction and renovation projects are expected to produce an average of 3.89 pounds and 70 pounds of waste per square foot, respectively. After completion of the waste calculating tool it was observed that new construction at the University produces and average of about 8.00 pounds of waste per square foot, and renovation generate approximately 70 pounds. Analyzing these results, though the estimated waste generation from renovation is accurate, it is shown that the University's production of new construction waste almost doubles average waste of other non-residential projects. This substantially larger quantity may be the result of a few problems.

University of Florida Significant Waste Generation

The following attempts to analyze the cause for the University's sizeable generation of waste as compared to other non-residential waste averages. Two possible arguments are provided and analyzed: irresponsibility and improper documentation.

Irresponsibility

The first possibility for the large generation of waste may be due to the University's lack of responsibility when generating waste. If this reason were true it would denote that the University takes little care when producing waste. It may imply that the University, the architect, and the contractors are responsible for designing with little thought, ordering excessive materials, using materials improperly, and taking minimal care to ensure the waste generated is properly management. However, the University strives to be sustainable, and producing excess waste would not be tolerated, especially on these jobs which utilize construction waste management plans. In addition, it is likely the contractors would be minimizing profits from this wasteful behavior and losing profit is not acceptable for contractors. Noting these facts, it seems irresponsibility is not the cause behind the University's significant generation of waste.

Improper Documentation

It was briefly mentioned early that the University had improperly documented projects' wastestream. All of the projects analyzed submitted documents to the USGBC to attain MRc2. Of the eleven projects initially studied, five included land clearing and site debris in their total waste generation and diversion figures. Though this may have been done accidentally, the requirements to achieve MRc2.1 and 2.2 clearly state, "evacuated soil and land clearing debris do not contribute to this credit" (USGBC, 2005). Though these numbers were successfully backed out of the wastestream numbers used for the waste calculator tool, there were other figures harder to remove which would not normally be included in a project's wastestream. Some of these quantities, mentioned earlier, include parking lot demolition and site stabilization. Though the materials from these processes were diverted, they should not count towards documentation a new construction project's wastestream. Therefore it is concluded that with documentation records inappropriate for this study, the waste calculation tool cannot accurately estimate the future wastestream of construction at the University.

Re-calculation of University of Florida Expected Waste Generation

Since the waste calculation tool could not successfully predict the University's future wastestream, another method must be used. As stated earlier, new construction projects, on average, produce 3.89 pounds of waste per square foot. To indisputably estimate future waste at the University due to new construction, this figure can be multiplied by the square footage of the future new construction projects registered with the USGBC. Tthe total square footage for future new construction is 1,023,973 square feet. The multiplication of these figures results in an estimated 3,983,225 pounds of new construction waste.

Renovation is said to produce an average of 70 pounds of waste per square foot. The University has plans to renovate 10,145 square feet in the future. Multiplying these quantities, future renovation at the University is estimated to produce 710,150 pounds of waste. Combining the waste from new construction and renovation will total 4,693,405 pounds of waste. This figure can be used to more accurately estimate future waste generation the University of Florida can expect.

Being an environmentally conscience institution, it is expected the University will continue to develop construction waste management plans in hopes of diverting as much waste as possible. Though the University has successfully diverted a variety of construction waste, during examination of the University's waste trends it was discovered that the University struggled with diverting gypsum board waste. The following section of the study will quantify the expected gypsum board waste the University will generate and struggle with diverting as a result of the sixteen future projects registered with the USGBC.

Estimating the Quantity of Gypsum Board Waste Present in the University of Florida's Future Wastestream

In order to quantify the amount of gypsum board waste the University will produce, it is necessary to understand the usual proportion of gypsum board waste present in the total C&D wastestream. The total C&D wastestream may be composed of as little as 4% to as much as 76% gypsum board waste. As stated earlier, numerous studies have been conducted in hopes of determining a percentage of gypsum board waste more appropriate to a specific project. The studies characterize projects by type of construction and then quantify the percentage of gypsum board waste present in the total C&D waste generated. Some studies were performed on individual project basis and district levels. Since studies were performed for both residential and non-residential new construction, renovation, and demolition projects, some results are applicable for this study. The following sections will determine the quantity of gypsum board waste the University can expect to produce as a result of new construction, renovation, and finally, all construction resulting from sixteen projects currently registered with the USGBC.

Gypsum Board Waste Generated from New Construction

In order to quantify gypsum board waste present in new construction debris, the waste must be compared to an appropriate study. Of all the studies examined, the most applicable study examined gypsum board waste generated from non-residential construction. This study examined the gypsum board waste generated from non-residential new construction projects on an individual basis, as well as, at two different district waste facilities. The study found that 7% to 11% of all non-residential new construction waste is composed of gypsum board.

It has been estimated that 3,983,225 pounds of waste will be generated during new construction of the sixteen future projects registered with the USGBC. To calculate the amount of gypsum board waste that will be present in this quantity, 7% to 11% of the expected waste must be determined. To do this, 3,983,225 pounds of new construction waste is multiplied by both 0.07 and 0.11. The two resulting numbers are the range of waste gypsum is anticipated to be present. The results conclude that the amount of expected gypsum board waste generated from sixteen new construction projects will total between 278,828 pounds and 438,158 pounds of waste. In tonnages these figures range from 139 tons to 219 tons of waste.

Gypsum Board Waste Generated from Renovation

Another study previously discussed determined the amount of gypsum board present in a non-residential renovation waste. This study is the most appropriate study to determine the gypsum board waste generated on University renovation projects. The study, conducted by a waste authority, concluded that 16% of non-residential renovation waste is a result of gypsum board debris.

It was estimated that the University will produce approximately 710,150 pounds of waste while renovating three of the sixteen future projects registered with the USGBC. To determine the amount of gypsum board waste that will be present in this wastestream, 16% of the total renovation waste must be calculated. To do this, the 710,150 pounds of estimated renovation waste is multiplied by 0.16. The resulting value concludes the future renovation debris at the University of Florida will include almost 113,624 pounds of gypsum board waste. Converted to tonnage, future gypsum board waste from renovation will total almost 57 tons.

Total Gypsum Board

Utilizing the estimated gypsum board waste quantities and the results found in previous gypsum board waste studies, it can be concluded that new construction will be responsible for between 139 tons and 219 tons of gypsum board waste and renovation waste will contain almost 57 tons of gypsum board waste. Combining these values, it can be determined that future projects at the University of Florida currently registered with the USGBC will result in the generation of between 196 tons to 276 tons of gypsum board waste.

It is also important to understand not only the weight of gypsum board waste the University will generate, but the approximate volume of the waste. In the Beck Pilot study performed in Orange and Seminole Counties, values were discussed explaining the gypsum board waste in both weight and volume. The study stated, “two temporary laborers could separate approximately 75 cubic yards (or approximately 21 tons) of drywall.” Another statement in the study discussing both weight and volume affirmed, “after streamline and improving the process, they could potentially separate approximately 225 cubic yards (or approximately 63 tons) per week.” Though these statements mean nothing in this context, the values are helpful in determining the volume of waste generated from an equivalent weight of gypsum board waste. To determine the cubic yards of gypsum board per ton of waste, 75 cubic yards was divided by 21 tons of waste. The same was method was used for analyzing 225 cubic yards, or 63 tons. Both calculations resulted in 0.28 cubic yards of waste per ton of gypsum board waste. The constant utilized in this study is helpful in determining the University's expected volume of gypsum board waste generated.

If the expected waste will total between 196 tons to 276 tons, these values must be multiplied by 0.28 to determine the expected volume of waste that will be generated. Multiplying both figures by the constant results in a range of 54.94 and 77.25 cubic yards of gypsum board waste. After analyzing the expected gypsum board waste in weight and volume, it is obvious the University should have a successful method for diverting gypsum board waste. Having yet to develop a suitable method, the University must take action against the detrimental environmental effects that will result from the school's growth.

Estimated Detrimental Effects Resulting from Anticipated Gypsum Board Wastestream

The detrimental effects of gypsum board waste disposal have been discussed earlier. Environmental impacts include taking up valuable space in landfills, transportation impacts, possible leaching, and the creation of a toxic gas. If the University neglects to divert any of the estimated 196 tons to 276 tons of gypsum board waste, Alachua County, the water supply, and nearby inhabitants could experience damaging effects.

Effects on Landfills

Currently the most common method for disposing of gypsum board waste in Alachua County is to have the waste hauled from the construction site to a local landfill, pay a fee, and have the wasted abandoned. The most obvious problem is the significant amount of waste taking up volume in local landfills. Calculated earlier, the total gypsum board waste is expected to take up between 54.94 and 77.25 cubic yards of volume. If the waste were transferred to a landfill, it would mean that over the time period of the sixteen projects between 54.94 and 77.25 cubic yards of landfill volume would be occupied with gypsum board waste and would be unavailable for other waste that may not have an option for recycling. Since most landfill operators are forced to remain within an allowable waste volume, the operators may soon turn away gypsum board waste and conserve the volume for debris that cannot be recycled, does not leach into their land, and will not produce a toxic gas that will be harmful to themselves and their workers.

Effects on Alachua County Water

The second environmental detriment Alachua County faces will occur when the landfilled gypsum board waste becomes moist, either by precipitation or groundwater intrusion. Groundwater intrusion is highly common in unlined landfills in Florida. Landfills containing gypsum board release calcium sulfate upon experiencing groundwater intrusion. Though the calcium sulfate is not as much of a threat as other chemicals, it will negatively affect the quality of water. For example, The U.S. federal secondary drinking water standard is 250 mg/L for sulfate (Townsend, 2003). It is not uncommon for the areas surrounding an unlined landfill to have concentrations above the allowable standard due to gypsum board waste. Like most of Florida, Alachua County sits atop an aquifer and has many areas highly vulnerable to negative effects, such as raised sulfate levels. If Alachua County experiences the disposal of gypsum board waste in the estimated magnitude, it is quite likely nearby groundwater sources will face unsatisfactory levels of sulfate.

Transportation Effects

Though hard to quantify, Alachua County will face detrimental effects due to the transportation of gypsum board waste. Construction projects commonly use onsite roll-off dumpsters to dispose of C&D waste. As stated by Florida Express Environmental (2008), a waste disposal company used by the University of Florida, "Twenty yard roll-off dumpsters are the most popular size with 85% of contractors." As determined earlier the University of Florida is expected to produce between 54.94 and 77.25 cubic yards of gypsum board waste over the course of the next sixteen projects. In order to transfer the anticipated waste the University will require three to four roll-off containers strictly for gypsum board debris. This is an estimate found by dividing the expected cubic yards of waste by 20 cubic yards, which is the size of commonly used roll-offs. This estimate does not take into account that the waste will be developed on different projects, in different locations, and at different times, thus requiring more roll-offs to transfer the waste.

The ability of construction projects to transfer the waste from the project site to the landfill will require energy usage and result in atmospheric emissions. Each of the roll-off transports will require transportation by a truck. Each of the trips will require energy to power the truck. The energy will most likely be diesel fuel and will result in atmospheric emissions. The energy required and the resulting atmospheric emissions will be dependent on the actual number of trips taken, the distances from the projects to the waste facilities, and the fuel required to power the truck for the total distances. The total environmental impact associated with the gypsum board waste transportation cannot be quantified, but will result in some amount of negative impact to the surrounding area.

Effects of Hydrogen Sulfide

Perhaps the most seriously considered detriment is the creation of hydrogen sulfide. As explained earlier, hydrogen sulfide is a colorless and highly toxic gas, recognizable by a distinctive odor resembling rotten eggs. The gas is created as the result of moist gypsum board in combination with an anaerobic condition. The toxic gas can be detected by human nose at less than 0.1 parts per million and has been measures at landfills in lethal doses at 250 parts per million (Townsend, 2008). Since the quantity of gas released is dependent on the amount of organic matter present, the concentration of dissolved oxygen, the pH level, and the temperature, it is difficult to quantify the concentration Alachua County may experience. In the best scenario, the debris will be scattered and limited hydrogen sulfate will result. However, if the worst scenario is experienced, nearby occupants may experience nausea, fatigue, shortness of breath, chest pain, and even death.

The landfills accepting the gypsum board debris may face other downfalls resulting from hydrogen sulfide. Some Alachua County landfills use onsite turbines to collect gases rising from the waste to generate energy. However, the gas may corrode energy generators, resulting in less energy production and increased costs for maintenance and decreasing energy supply. This may also lead to landfill operators rejecting the disposal gypsum board waste.

Loss of Natural Resources

The final environmental detriment resulting from gypsum board waste disposal is the ultimate loss of a raw material. With the recent implementation of the green building trend, the importance of protecting natural resources is finally evident. Other than the recycled paper backing, on average, gypsum board is composed of 99.5% raw gypsum. The University of Florida's anticipated generation and disposal of 196 tons to 276 tons of gypsum board waste will result in the disposal of a sizeable quantity of the naturally occurring resource. Though the industry has not experienced a shortage in sometime, the raw mineral should still be protected.

CHAPTER 6
PROPOSAL

Currently planning the construction of sixteen on-campus structures, The University of Florida has taken the first of many environmentally conscious decisions by registering all of the projects with the USGBC. Hoping to attain at least a Gold certification on all sixteen projects, the University plans on performing a number of tasks beneficial to the well being of the environment. Analyzing previous project performance, the University has been successful at initiating and implementing many sustainable techniques and trends, including diverting construction waste with use of construction waste management plans. Unfortunately similar to project owners around the world, the University has had trouble diverting gypsum board waste due to the scarcity of nearby gypsum board recycling programs. Hopefully with use of the following proposal the University of Florida will successfully initiate another sustainable program: a gypsum board waste diversion program. Implementing this program the University can limit their negative environmental impact and ultimately provide others with suitable recommendations to do the same.

Proposal to The University of Florida For A Successful Gypsum Board Waste Diversion Program

After analyzing the successes and failures associated with past gypsum board recycling programs and investigating the capabilities of the University of Florida, the following proposal has been determined to be the most suitable approach for gypsum board waste diversion for the University. The following proposal is presented to the University for successful diversion of the anticipated 196 tons to 276 tons of gypsum board waste generated on future campus construction projects. The program will require two main goals to ensure success. The first will require the purchase of equipment capable of recycling gypsum board waste. Second, the University should follow the guidelines offered below, as they have been created to ensure the University's success in gypsum board waste diversion. The following will propose appropriate recycling equipment and outline gypsum board diversion guidelines for the University and their subcontractors to follow.

Gypsum Board Recycling Equipment

Although a few years ago there were no machines capable of recycling gypsum board waste, today there are many qualified machines. Most gypsum board recycling procedures involve inserting gypsum board waste, separation of the components, and outputting gypsum and paper independently. Gypsum board recycling equipment ranges from handheld devices to machines that must be transported by semi-trucks. For the needs of the University, equipment somewhere in between will be appropriate.

The appropriate equipment must be selected based on two factors: 1) the quantity of gypsum board waste to be diverted in a specific time frame and 2) the output needed from the equipment. To select appropriate equipment the future gypsum board generation must be analyzed for each project by quantity and by anticipated gypsum board installation duration. Since the quantity of gypsum board waste would be generated of the course of a few weeks, it is necessary to select equipment capable of recycling the gypsum board generated within a reasonable time period. The time frame for recycling the gypsum should not extended much more than the timeframe scheduled for gypsum board installation, and therefore, waste generation. This will limit the possibility for weather damage and limit the space needed for storage.

After analyzing the anticipated gypsum board waste generated for each future University construction project, the expected gypsum board waste will range from 0.76 tons to 35 tons for any one specific project. Utilizing RSMeans Building Construction Cost Data (2007), it is expected that the largest project will require 10 working days, or approximately 2 weeks, to perform the gypsum board installation. Therefore, the gypsum board waste diversion process should be scheduled in the same time frame. To select the equipment capable of handling the gypsum board waste produced on the largest project, 35 tons of waste must be able to be reduced in two weeks. Since the equipment is rated on a ton per hour basis, the two weeks can be converted into 80 work hours. To calculating tons per hour, the 35 tons of expected gypsum board waste must be divided by the 80 hours available to reduce the waste. The equipment selected must be capable of diverting 0.44 tons of gypsum board waste in an hour.

The second requirement for the gypsum board reducing equipment examines the type of output desired. Some machines simply break down the gypsum board into small pieces, while other equipment can separate the gypsum from the paper for individual recycling and can do so in a variety of particle sizes. For the purposes of the University of Florida, the desired output will result in the gypsum and the paper separated. Since the gypsum will be used as a soil additive, the preferred gypsum particle size is fine particles similar to that of a dust or powder. The size of the paper is of no importance. The paper will be recycled as part of the usual jobsite recycling program.

Andela AGBR-01: The two criteria for selecting the gypsum board reducing equipment have been analyzed. The equipment must be capable of diverting at least 0.44 tons of gypsum per hour and must produce an output of fine gypsum particles separate from paper. After researching gypsum board diversion equipment, a company by the name of Andela Products, Ltd. was discovered. Andela Products, Ltd. sells a variety of gypsum board recycling equipment options.

Examining the options available, a selection was made based on the two explained criteria and the Andela AGBR-01 was selected. The Andela AGBR-01 is a gypsum board reducing machine capable of diverting one to three tons of waste per hour (Andela Products, Ltd., 2007).

Therefore, this machine is capable of diverting 0.44 tons per hour, handling the requirements of the most demanding project. Secondly, the Andela AGBR-01 output produces gypsum in a "powder and granular gypsum mix." Not only is the equipment capable of producing an output of gypsum in the appropriate size, the machine utilizes screens to separate the gypsum dust from the larger sized pieces of paper for individual recycling. This too is satisfactory for the University of Florida's soil additive needs. The Andela AGBR-01 is available at Andela Products, Ltd. website. As of this time, Mr. John Andela, head of equipment sales, was not available to provide a cost for the equipment.

Gypsum Board Diversion Program

Following the proposed guidelines and implementing a gypsum board diversion program will require the participation of a variety of individuals. The main participant should be a member of the University of Florida team. Perhaps this individual should be a member of the University of Florida's Facilities Planning and Construction team or an owner's representative. The main participant is responsible for ensuring all parties commit to and follow the guidelines for the recycling program. Other individuals required for program success will include a designated onsite construction project team member to act as a diversion coordinator, drywall subcontractor, drywall hangers, and a designated laborer to run the gypsum board diversion equipment.

Overall, the guidelines aim to collect all non-contaminated gypsum board waste generated during new construction and renovation and input the material into the purchased AGBR-01 equipment. Once separated from the paper the gypsum will be scattered as a soil additive onto any applicable landscaping area. If the project does not have a need for the soil additive, the gypsum will be offered to the many agricultural locations at the University of Florida, which currently purchase gypsum to use as a soil additive.

Tables 6-1 through 6-3 collectively form a series of guidelines proposed to the University for gypsum board waste diversion. The guidelines will be helpful in the initial preconstruction phases of new construction projects. Since the recycled gypsum will be used as a soil additive, only non-hazardous gypsum board waste should be recycled. Therefore during the three scheduled renovation projects, care must be taken to ensure contaminated gypsum is cared for separately.

The guidelines are organized in a timeline fashion and discuss tasks that should be performed during preconstruction, construction, and upon gypsum board reduction. Each task includes a brief description of the requirements necessary to perform the task. Finally, a responsible party is designated for each task. Proposed to the University of Florida collectively, Tables 6-1 through 6-3 serve as a tool for initiation and implementation of a successful gypsum board waste diversion program at the University.

Preconstruction tasks

Table 6-1. University of Florida gypsum board waste diversion proposal: preconstruction tasks.

Task	Description/Requirements	Responsible Party
Designate a Gypsum Board Diversion Coordinator	1. Select a member of the UF team to act as a coordinator for gypsum board waste diversion throughout the course of the project. 2. This individual should be a member of the construction team and be onsite daily during construction. 3. If an individual responsible for LEED tasks has already been selected, they are a suitable candidate for Gypsum Board Diversion Coordinator.	UF Team
Require Subcontractor Participation	1. When selecting the drywall subcontractor require their participation in gypsum board waste diversion. 2. Include a requirement for gypsum board waste diversion in the subcontractor's contract. 3. Require the subcontractor commit to producing a minimal amount of gypsum board waste and manage any gypsum board waste that is generated. 4. Subcontractor must require drywall hangers to keep excess gypsum board separate from other onsite waste.	UF Team

Table 6-1. Continued

Plan for Gypsum Board Diversion	1. Acquire bins specifically for gypsum board waste accumulation. 2. Acquire a variety of sizes. Large bin for mass accumulation, smaller bins, perhaps rolling garbage cans, for workspace collection. Smaller bins can be dumped in large bin once filled or upon completion of work.	General Contractor/ Diversion Coordinator
Arrange Site Plan to Promote Gypsum Board Diversion	1. Strategize appropriate locations for gypsum board waste bins. 2. Gypsum board waste should be kept in a dry location. 3. Smaller bins should be placed frequently or capable of relocation to avoid incorrect disposal due to worker objection.	General Contractor/ Diversion Coordinator
Ensure Equipment Availability	1. Reserve equipment in accordance with scheduled drywall installation or shortly thereafter to avoid prolonged storage of gypsum board waste, possible weather damage, and conflicts with other projects.	UF Team and General Contractor/ Diversion Coordinator

Construction tasks

Table 6-2. University of Florida gypsum board waste diversion proposal: construction tasks.

Task	Description/Requirements	Responsible Party
Ensure Gypsum Board Waste Separation	1. Supervise drywall hangers' placement of gypsum board waste into the designated bins.	Diversion Coordinator and Drywall Subcontractor
Gypsum Board Waste Separation	1. When gypsum board waste is generated, be sure it is deposited in the appropriate bins. 2. When smaller, rolling cans are full, relocate gypsum board waste into larger bin. 3. On renovation projects, ensure contaminated gypsum board waste is not placed in bins allotted for recyclable gypsum board waste.	Drywall Hangers
Designate a Laborer to Run Gypsum Board Waste Reducing Equipment	1. Designate a capable individual to run the gypsum board waste reducing equipment. 2. Be sure individual understands how to operate equipment and the associated risks.	Diversion Coordinator
Reduce Gypsum Board Waste	1. Feed Andela AGBR-01 equipment with gypsum board waste scraps. 2. Collect and bundle the reduced gypsum pieces for transfer to soil site. 3. Collect separated paper and recycle normally.	Designated Gypsum Board Waste Reducer

Diversion tasks

Table 6-3. University of Florida gypsum board waste diversion proposal: diversion tasks.

Task	Description/Requirements	Responsible Party
Use Reduced Gypsum as Soil Additive	1. Locate the onsite area planned for landscaping. 2. Scatter reduced gypsum over soil at a rate equal to 1 pound per 25 square feet of land. 3. If excess gypsum is present, locate a University of Florida agricultural site ideal for soil additive and scatter the remaining gypsum. 4. Immediately irrigate the soil treated to allow the additive to penetrate.	Diversion Coordinator and UF Team
Document Diversion	1. Keep accurate logs of total gypsum board waste generated, gypsum board waste diverted, dates, and other corresponding information. 2. Totals will be helpful in determining eligibility for LEED-NC MRc2.1 and/or 2.2.	Diversion Coordinator
Monitor Effects of Gypsum	1. Monitor soil and plant growth. 2. Document benefits and detriments associated with gypsum usage. 3. Utilize documented information to improve future processes.	UF Team

University of Florida Benefits From Program Gypsum Board Diversion Implementation

If properly implemented, the proposed guidelines are capable of recycling the majority of gypsum board waste expected to be generated as a result of sixteen future University projects. Though it is not certain all of the gypsum board waste generated from renovation will be able to be recycled, it is possible that all new construction waste can successfully be diverted. The plan would ensure between 196 tons to 276 tons of gypsum board waste, as well as a portion from renovation waste, could be successfully diverted.

Limit Anticipated Detriments

Numerous benefits could result from the diversion plan. Most obvious would be the reduction of the negative impacts previously discussed. The 54.94 and 77.25 cubic yards of gypsum board waste may be diverted from the landfill and therefore allow the disposal of more compostable materials. Other successes at the landfill would be reduced corrosion of turbines from hydrogen sulfide gases and therefore lower maintenance costs.

Workers at the landfill and nearby neighbors could also benefit from the limited hydrogen sulfide gas. Other than limiting the unpleasant odor, illnesses resulting from the gas may also be minimized. Also nearby the landfill, groundwater stands to benefit from the diverted gypsum. Perhaps the diversion will minimize the chance for high levels of calcium sulfate that could possibly contaminate the aquifer. Since this plan does not require transporting the diverted gypsum to any facility, transportation impacts and atmospheric emissions will also be reduced.

Finally, though the proposed diversion plan does not deter the gypsum well enough to continue the life cycle, it still limits the amount of raw gypsum that must be extracted. Utilizing the diverted gypsum as a soil additive, limits the need to mine raw gypsum for the same purpose. As stated earlier, 1.8 million tons of gypsum is mined every year strictly for use as a soil additive. If the University can recycle gypsum on campus, they can successful reduce the mining of gypsum for any University of Florida soil needs.

In fact, the University of Florida recommends using gypsum as a soil additive for farming small fruits. In a 1998 disaster handbook the University recommended, "if the sodium content is 250 ppm or more, internal drainage problems will occur. This can be corrected somewhat by the use of gypsum as a soil additive. Apply at the rate of 2 ounces of gypsum per square foot of area (2¾ tons per acre) and immediately irrigate to move the material into the soil profile" (University of Florida Cooperative Extension Service Institute of Food and Agricultural Science, 1998).

Improved Soil Conditions

Discussed earlier, other benefits from the proposed plan will include improved soil conditions for treated soil. Utilizing gypsum board as a soil additive will improve the soil's workability. Gypsum also allows easier water penetration and ultimately improves irrigation for the crop, grass, or plant. Gypsum present in the soil will also counter the corrosive affect produced by alkalinity. The three advantages of gypsum use as a soil additive pose no threat to existing soil conditions or crops. In fact, gypsum application to soil acts without affecting the pH level of the soil. Owning thousands of acres dedicated to agricultural use or conservation, the University of Florida could experience benefits including improved irrigation, improved soil workability, and overall improvement in growth if the gypsum board waste is reduced and utilized as a soil additive.

Savings

Implementing the gypsum board waste diversion program, the University is faced with a variety of opportunities to save money. The most obvious will be the elimination of roll-off pulling fees or landfill tipping fees for gypsum board waste disposal. In Alachua County tipping fees are estimated to be in the range of $15 to $20 per ton of waste. As found with national averages and results from applicable studies, the University is expected to generate between 196 tons to 276 tons of gypsum board waste over the course of the next sixteen projects. Disposing of the gypsum board waste alone will cost the University between $2,940 and $5,520. This estimate only provides base savings. The University also eliminates the cost for transporting the waste and eliminates any future costs resulting from increases in tipping fees.

The University may experience other monetary savings resulting from future government incentives. The county of Alachua currently offers incentives for energy generation, energy efficiency, and a commitment to green infrastructure. Though there is not currently an incentive for waste diversion, a program may be developed in the future that provides an incentive specifically for waste management or in a broader scope for sustainable practices. If such an incentive program is created, the University will be an established and credible candidate.

Avoiding the Future Disposal Ban of Gypsum Board Waste

As already seen in parts of Canada, and explained during discussion of New West Gypsum Recycling, Inc. program, governments have already began to ban the disposal of gypsum board waste in landfills. Not only are governments unhappy with the effects of mass disposal of the material, landfill operators that have experienced generator corrosion, employee health issues, or unhappy neighbors have began to ban the debris as well. If the University of Florida takes initiative now, the University will avoid a future setback if local government or landfills operators refuse to dispose of gypsum board waste.

If gypsum board waste is banned, the University may have an opportunity to utilize the program to acquire profit. Having already implemented and improved the program, the University might be able to accept gypsum board waste generated from other Alachua County projects and divert that waste as well. Accepting the waste, the University will also be able to accept a reasonably priced tipping fee. If the disposal is banned, contractors will be in need of a method to divert the waste and will be forced to pay whatever fee the University sees fit.

Finally, upon collection and reduction of gypsum board waste, the University may have more gypsum than needed for soil additives, and may sell the gypsum to others. As stated earlier, the average price for a 40 to 50 pound of recycled gypsum is about $4.00 per bag. Depending on the amount of excess gypsum, the University could see a significant profit. Understanding the possibility for a future ban of gypsum board waste disposal, implementing the program now may avoid the future shock and even provide the University with additional opportunities for monetary gain upon a ban of gypsum board waste disposal.

Reinforcing the University of Florida's Reputation

As known by many, the University of Florida has a stellar reputation for education and research. The University of Florida frequently increases acceptable standards for public universities. As mentioned earlier, the University takes pride in being a highly sustainable campus and has achieved much success with the green building movement. Requiring green certification from every campus project was only the first step in the University's commitment to the green building movement. Implementing the gypsum board waste diversion program would continue to reinforce the University's commitment and leadership in sustainable practices.

Even with numerous attempts, there has yet to be a successful gypsum board recycling program in the State of Florida. Contractors and waste facilities owners around the state are in search of a nearby facility capable of diverting the waste. With so many individuals interested in a gypsum board waste recycling program it would be wise for the University to take initiative. With the University's existing resources, it would be no drastic feat to successfully implement the diversion program.

Implementing the program at the University would attract the attention of the numerous individuals and organizations currently in search of a gypsum board diversion program. Not only would the positive attention reinforce the University's prestigious reputation, it was also provide the University with another opportunity to lead the community, and possibly the State of Florida. Implementation of the gypsum board diversion program would just be another successful attribute of the University of Florida.

CHAPTER 7
CONCLUSION

Over 40 tons of gypsum board waste is disposed into landfills around the world everyday. With only a few successful gypsum board recycling programs worldwide, local construction projects are faced with difficulty finding a diversion method for gypsum board waste generated in tons on each project. With no option for diversion, the gypsum board waste is transferred to a local landfill where the waste decomposes and causes environmental concerns such as groundwater contamination, toxic gas, and health issues.

Faced with the same predicament, the University of Florida may find it difficult to maintain their impressive reputation for initiation of and commitment to sustainable construction practices as long as the University is producing gypsum board waste by the tonnage. With countless valuable resources and dedication to sustainable construction, it would not be challenging for the University to alter their current practices to ensure additional environmental benefit. Already planning the construction of sixteen additional LEED-NC Gold certified projects, it is time the University implement a program for gypsum board waste diversion.

After attempting to create a waste estimating tool, it was discovered the University currently utilizes improper methods for documenting construction waste. In order to correct this, it is recommended the University revisit the methods currently used to document waste and formulate a more successful technique to document results more accurate to the actual generated wastestream. After the alteration ensures accurate results, a waste estimating tool can again be attempted. Until these quantities are reliable, estimating the quantity of future gypsum board waste must be predicted with use of national averages and credible individuals, as was performed in this study.

After analysis of the sixteen intended projects it is found that the University can expect to generate between 196 tons to 276 tons of gypsum board waste. A series of previously attempted gypsum board recycling programs were analyzed and manipulated to best fit the needs and capabilities of the University of Florida. The proposed solution for gypsum board waste diversion requires two main phases: purchasing gypsum board recycling equipment and following diversion guidelines created specifically for the University of Florida. Upon proposal acceptance, it would be possible for the University to divert the gypsum board waste, lessen harmful environmental impacts, and experience monetary gains.

The proposal details a series of tasks to be performed before construction, during construction, and after gypsum board waste reduction. The main tasks during preconstruction include preparing the jobsite with proper recycling bins and bin location and commitment from the general contractor, drywall subcontractor, and drywall hangers. During construction the main tasks include ensuring proper separation of gypsum board waste, safe use of the gypsum board waste reducing equipment, and monitoring the success of the process by designated management. The final tasks include finding a suitable location to scatter the recycled gypsum and observing the effects of gypsum on the treated soil. Following the tasks detailed in the guidelines will ensure success of the gypsum board recycling program developed to be suitable for the University of Florida.

If implemented and followed the University can expect a reduction in environmental impact and increase in savings and opportunities. Implementing the proposed gypsum board waste diversion program will result in a series of environmental benefits. Impacts that have resulted from gypsum board waste in landfills for years will decrease at an amount proportional to the University's ability to divert the waste. Environmental determines such as generation of toxic hydrogen sulfide gas, leaching of calcium sulfate into groundwater, and ill landfill workers and neighbors are all expected to decline with the diversion of large amounts of gypsum board waste from landfills. Expected benefits for the University include monetary gain, soil improvement, and ability to avoid a future problem if gypsum board waste disposal is banned.

Perhaps the most important success of the program will be the continued commitment of the University of Florida to sustainable practices and the wellbeing of the environment. At a time when one can clearly see the importance of joining the green building movement and a number of individuals are currently looking for a solution for gypsum board waste, the University of Florida is again faced with an opportunity to reinforce their reputation and demonstrate their ability to lead their peers with successful generation and implementation of a gypsum board waste diversion program.

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BIOGRAPHICAL SKETCH

Jacqueline Wade Mustakas was born May of 1985 in Winter Springs, Florida. Jacqueline is the daughter of John and Mary Mustakas and sister to Patrick and Amanda. Growing up, Jacqueline was very focused in her studies and participated in gymnastics, softball, weightlifting, and cheerleading. Jacqueline graduated high school in 2003 and began her college education at the School of Architecture. After two years, Jacqueline changed her major and entered the M.E. Rinker, Sr. School of Building Construction. During her undergraduate education Jacqueline participated in extracurricular activities such as Sigma Lambda Chi Honors Construction Fraternity and the University of Florida Green Team. Jacqueline graduated with a Bachelor of Science in Building Construction and an associates of arts in May 2008. She graduated sixth in her class with highest honors and a GPA of 3.93. Nominated for the College of Design Construction and Planning Academic Achievement Award, Jacqueline was asked to give the graduation speech at the Rinker School Graduation Dinner. Jacqueline also completed an Honors Thesis titled "Approaching and Achieving Suitable Innovation Credits."

Interested in continuing her education, Jacqueline applied to graduate school at the M.E. Rinker, Sr. School of Building Construction. Jacqueline worked while completing graduate school as Graduate Research Assistant responsible for researching and resolving current problematic trends in the construction industry. Jacqueline focused her thesis on assessing the current downfalls of gypsum board waste. While completing graduate school, Jacqueline also achieved her LEED Accredited Professional Certification. Jacqueline graduated with a Master of Science in Building Construction with a concentration in Sustainable Construction in May 2009.