GREENHOUSE GAS EMISSIONS REDUCTIONS FROM LEADERSHIP IN ENERGY AND ENVIRONMENTAL DESIGN RECYCLING PROGRAMS

By

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A THESIS PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT
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To my Mom

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This study incorporates waste data on the United States Green Building Council (USGBC) Leadership in Energy and Environmental Design (LEED) recycling programs at the University of Florida and uses the United States Environmental Protection Agency's Waste Reduction Model (WARM) to convert the diverted waste into greenhouse gas emissions savings. In the study steel and carpet provide the best opportunities for greenhouse gas emissions savings when recycled. The study compares the weight of all materials recycled or diverted from landfills on the projects to the emissions impacts of that material. Although concrete doesn't offer the same opportunity on a mass basis, because of its extensive use concrete also offers a good opportunity for greenhouse gas emissions savings when recycled. Currently LEED recycling programs focus only on weight or volume of material diverted and not environmental impacts or savings. The study suggests that the focus should be changed to recycling or diverting materials based on emissions impacts rather than weight or volume alone.

CHAPTER 1
INTRODUCTION

The American Way

The United States economy has evolved into a society based on consumerism and the principle of steady growth. For most of the 19th and 20th century, economic growth has been the major public concern for the construction industry. Environmental issues such as waste and resource management were typically not discussed because resource prices were cheap and land was bountiful. The environment in general was put on the backburner as the U.S. grew to become a world superpower.

The U.S. is the third largest country in land area in the world with 9,629,091 square kilometers. Europeans arrived in the 1500s and began to spread across the Americas. With such a large land area came resource use that could not be sustained. Early American history is a perfect example. European settlers swept across the land claiming it as their own and as the population grew, Americans just moved further west consuming natural resources. Early Americans didn't understand the ways of the Native Americans who wasted nothing and led sustainable lifestyles. Conflict between early Americans and the Native Americans was primarily caused by the overuse and waste of abundant resources. The idea of free land, the gold and silver rush, and the fur trade are all perfect examples of early Americans taking advantage of abundant natural resources. Gold miners would begin mining and once all the gold was mined they would just move to the next spot up the river. Fur traders would shoot anything that moved with no concern for survival of the species. The American bison which once roamed nearly all of North American was nearly killed off entirely because of over hunting. Old western movies showing men on horseback gunning down as many bison as possible and horse carriage races to claim free land accurately depict the mentality of early Americans.

In the late 1700s and early 1800s the industrial revolution brought the need for more energy production. Coal and oil were discovered in large quantities throughout the world and a complete transition to the use of fossil fuels occurred in the 20th century as fossil fuel prices were extremely cheap and thought to be unlimited. In 1956 the theory of “peak oil” was put forward by M. King Hubert which described that the fossil fuel era would be very short in time (Kibert 2008). This theory was virtually ignored by the mainstream public as prices remained low even as demand grew at astonishing levels. No importance was put on the efficiency or environmental effects of motors or processes as long as it remained profitable. Then, in 1973 a historic oil embargo occurred resulting in oil prices quadrupling in less than 4 months and consumers waiting in hour long lines at only the chance of getting gas (U.S. Department of State 2009). During the crisis there was a short lived movement towards renewable energy. President Nixon vowed to wean the U.S. off foreign oil and to rely on renewable energy for all future needs. Once the embargo ended only six months after it started oil prices dropped to the previous low prices and public concern all but died. The movement towards renewable energies disappeared as it once again became feasible to buy oil. When prices are low Americans tend not to take notice of how much waste is involved in a process or material. In mainstream America, change, almost always comes down to the dollar.

The mindset that resources are abundant and endless is slowly changing. Open land in many areas of the country is now considered a limited resource. Many cities and areas along the eastern and western seaboard are becoming completely built out with no land to spare. The majority of South Florida is built out and now land prices are on the rise. Oil prices reached historic highs in 2008 as the demand increased and supplies stayed the same (WTRG 2009). Material prices for steel, aluminum, copper and cement along with many other important building materials also broke records (ENR 2009) as China's demand for materials and resources increases. With increased oil prices came increased transportation costs causing Americans to take notice and realize that we can no longer afford to be wasteful with our natural resources.

In comparison to most European countries the United States environmental policy is less stringent (Hayward 2008). European countries have taken damage to the environment much more seriously than the U.S. has for decades. European countries are small and connected to one another, and as a result actions in one country can influence several of its neighbors. America only has 2 countries that boarder it with most of the population living no where near a bordering country. In Europe rivers run through multiple countries and polluted air crosses over close borders. When one country releases chemicals into the atmosphere that cause acid rain in another country problems begin to arise. This close proximity and limited amount of land and resources compared to the U.S. has forced European countries to be more environmentally friendly. Recycling programs inside the European Union averaged 37% recycling rates (Institute for Environmental Strategies 2008) while in 2005 recycling in the U.S. averaged only 31.7% (EPA 2008). Also another major difference between European countries and the U.S. is the stance on greenhouse gas emissions. The United States chose not to ratify the Kyoto Protocol which would bind the U.S. to reduce its GHG emissions by 7% by the year 2012. The President commented that the U.S. would not ratify the Kyoto Protocol because it would hinder economic progress (Associated Press 2005). Every major country in Europe ratified the Kyoto Protocol. Also when comparing buildings in Europe they are designed and constructed in much more environmentally friendly ways.

Construction and Buildings in America

Construction has always been a major force of growth in the U.S. From the beginning of colonization, America has been constantly constructing more buildings, roads, and infrastructure.

In 2008 the construction industry contributed 13.2 trillion dollars to the gross domestic product which is 13.4% of the total GDP (U.S. Census Bureau 2008). Of the 13.4%, commercial and residential construction contributed 6.1% while industrial construction contributed 7.3% (U.S. Census Bureau 2008). In the U.S. buildings consume large amounts of natural resources, both renewable and non-renewable. In the U.S. buildings account for 38.9% of total primary energy use (EIA 2008d), 72% of electricity use, 13.6% of potable water use (USGS 2005), and 40% of raw material use (Lenssen and Roodman 1995). Buildings are also responsible for 38% of annual U.S. GHG emissions (USGBC 2009).

Construction in the U.S. produces 136 million tons or 35% of all annual waste (EPA 1998a). Historically, construction activities have done little to help the environment. However, in the past 20 years issues such as global warming and resource and land management have become hot topics in the U.S. which has lead to more environmentally friendly buildings and construction processes. These issues have led to a mainstreaming of the green movement inside the United States.

Green Movement

The "green" movement is based on the principal of sustainability, which is completely opposite of the current American wasteful lifestyle. Sustainability is defined by the United Nations as "meeting the needs of the present without compromising the ability of future generations to meet their own needs (WCED 1987)." A smaller movement inside the green movement is the sustainable construction movement, also known as the high performance green building movement. Sustainable construction is defined by the International Council for Research and Innovation in Building and Construction as "creating and operating a healthy built environment based on resource efficiency and ecological design" (CIB 1994).

The high performance green building movement is propelled by three major forces (Kibert 2008). The first is growing evidence that humans are increasingly destroying the planet's ecosystems and altering earth's natural systems while increasing population and consumption to unsustainable levels. The second major force is increasing demand for natural resources by developed countries like the United States and developing countries like India and China. This increase in demand produces shortages and results in higher prices. The third force is the high performance green building movement coincides with other major green movements in other areas such as manufacturing, tourism, agriculture, medicine, and public sectors. Many companies are beginning to push green advertising to help promote and sell their product.

In 1993 a group of individuals recognized that the U.S. was undergoing the beginning of a mainstream green movement and that a green building rating system needed to be developed. This group founded the United States Green Building Council (USGBC) in 1993 and began work on Leadership in Energy and Environmental Design 1.0 in 1994. LEED 1.0 was released in 1998 after 4 years in the developmental process. LEED 1.0 was produced by regulators and industry experts who wanted to create a rating system that could be used by a wide range of participants. Also by gathering input from so many different experts and regulators insured that the system would be widely accepted. From the start, the USGBC decided that LEED should not be forced by regulations but rather market driven. This meant that green buildings would have to distinguish themselves in the market place by having a higher value than comparable conventional buildings. This resale value would be due to decreased long term costs such as maintenance and energy costs. LEED 1.0 was a trial and testing version with only twenty buildings being certified under the system.

LEED 2.0 was released in 2000 as a dramatically changed version from LEED 1.0. Then in 2002, LEED 2.1 was released which was nearly identical to LEED 2.0 but had simplified the paperwork submittals required for documentation. The current version of LEED is version 2.2. LEED 2.2 has only minor changes from LEED 2.1 with the major change being the creation of the LEED online website. This website handles all of the documentation process and eliminates all of the physical paperwork. LEED 2.2 is made up to 69 total points dived into six major categories. LEED 2.2 contains seven prerequisites, which are conditions that award no points but all must be met to gain any certification level (USGBC 2002).

The first category in LEED 2.2 is Sustainable Sites which contains one prerequisite addressing erosion and sedimentation control. Sustainable Sites has a maximum of 14 awardable points. The second category is Water Efficiency which contains no prerequisites and has a maximum of 5 awardable points. The third category is Energy and Atmosphere which contains three prerequisites, fundamental building systems commissioning, minimum energy performance, and CFC reduction in HVAC and refrigerant systems. Energy and Atmosphere has a maximum of 17 possible points. The fourth category is Materials and Resources which contains one prerequisite, storage and collection of recyclables. Materials and Resources has a maximum of 13 possible points. The fifth category is Indoor Environmental Quality which has two prerequisites, minimum IAQ performance, and environmental tobacco smoke control. Indoor Environmental Quality has a maximum of 15 possible points. The sixth category is Innovation and Design process and contains no prerequisites and a maximum of 5 possible points. The sixth category is an extension of the five other categories in that four of the possible points are based on going above in beyond in categories one through five. LEED 2.2 has a total of 69 possible points; achieving 26-32 points is certified, 33-38 points is silver, 39-51 points is gold, and 52-69 points is platinum rating (USGBC 2002).

LEED is continually being revised and adjusted by the USGBC in order to become a better green building rating tool. A new updated version of LEED consisting of 100 possible points is set to be released in 2009. Since its creation LEED has been exponentially growing. By 2010 it is estimated that 10% of all commercial construction projects will be green (MGH 2006). Currently there are 2,271 certified projects and another 17,725 registered projects. There are LEED projects in all 50 states as well as 89 countries (USGBC 2009).

Global Warming and Climate Change

The idea of global warming was first published in 1896 by a Swedish author who proclaimed that the burning of fossil fuels would slowly raise the earth's average atmospheric temperature (Weart 2007). This idea was denounced and many scientists provided reasons why the buildup of carbon dioxide would not affect the earth's temperature. In the 1930's the temperature changes were acknowledged; however, the scientific consensus was that it was a natural cycle that occurred on earth. In the 1950's Cold War concerns about weather and sea levels caused increased funding for global warming studies. With more time and money invested in the issue, better models were developed and it was discovered that in fact carbon dioxide levels were on the rise and that with that rise will come increased temperatures. Over the next 20 years the models that predicted temperature change over thousand of years were revised and improved to show that temperature changes could occur much more rapidly, within a few centuries.

The idea of climate change has been around for over a century; however, only in the past 20 years has the idea been embraced by larger numbers of scientists and the public (Weart 2008). Global warming is a topic that Americans are aware of but unable to fully understand. The idea that emissions from tailpipes and power plants could actually change the temperature on earth astounds some people. In the past, the theory of global warming has been brushed off and ignored. More recently however, the impacts of many weather events like hurricane Katrina and the reports of actual temperature change have further pushed the idea of global warming into the main stream media. Global warming and climate change are now phrases that nearly every American has heard. Due to the concerns about global warming and GHG emissions, companies and business are going green and in the commercial construction industry that usually means turning to the LEED rating system.

One of the categories in LEED is material and resources which contains two available points for construction recycling. A project that reaches a waste diversion rate of between 50% and 75% receives 1 point. A project that reaches a waste diversion of more than 75% receives 2 points and a project that reaches beyond 95% is eligible for a third exemplary performance credit (USGBC 2002). LEED certification is an expensive process and certain points take more money than others to achieve. In comparison to many other LEED points, a construction waste management program takes little additional capital or in some areas can even be profitable to the owner and contractor. Many owners choose to pursue the waste management credits because of the low cost associated with it. A 2006 green building report of 111 LEED projects showed that 80.2% of the projects achieved at least the 50% waste diversion rate and 56.8% reached the 75% waste diversion rate (MHC 2006).

Historically, the cheapest thing to do with construction waste had been to dump it in a landfill. Barriers to recycling include: the cost of collecting, sorting and processing, the low value of the recycled content material in relation to the cost of a virgin based material, and the low cost of construction waste disposal fees (EPA 1998a). In the past few years with the escalation of material prices and the increase in fuel costs it is becoming much more economical to recycle. Depending on the location and the material being recycled it can even be profitable for contractors to recycle construction waste.

Construction and buildings in the U.S. consume 40% of raw material use (USGBC 2009) and with this usage comes GHG emissions. The best way to reduce these emissions is through source reduction, defined by the EPA as "altering the design, manufacture, or use of products and materials to reduce the amount and toxicity of what gets thrown away." The second best opportunity to reduce GHG emissions for most materials is recycling (EPA 2006). "For these materials, recycling reduces energy related CO2 emissions in the manufacturing process and avoids emissions from waste management" (EPA 2006). When compared to landfilling, recycling is a much more sustainable process.

The research will focus on evaluating overall GHG emissions by sector and contributor and then evaluate the impact of LEED construction recycling programs on GHG emissions reductions at the local, statewide, nationwide, and worldwide levels. The author will use data collected at the University of Florida on multiple LEED projects and convert this waste diverted into GHG emissions reductions. GHG gases are reduced during construction waste recycling because landfilling and waste incineration are avoided and because recycled products generally require less energy to produce than virgin materials. First a literature review of greenhouse gasses was conducted to determine what industries and sectors contribute to total worldwide GHG emissions. The literature review will start by looking at a worldwide view of GHG emissions its contributors.

CHAPTER 2
LITERATURE REVIEW

Greenhouse Gas Emissions Background Information

Role of Greenhouse Gases on Earth

Earth is a very complex and sophisticated planet that has supported life for billions of years. There are thousands of planets of which only a few have the right balances to support life. On earth greenhouse gases are one of the main reasons that earth can support life. Greenhouse gases are gases that trap the suns radiation in the atmosphere and set the temperature on earth. Sunlight enters the earth's atmosphere and strikes the earth's surface heating it up. The earth then sends this energy back towards space in the form of infrared radiation which greenhouse gases absorb and retain. This causes the earth's atmosphere to heat up depending on the level of greenhouse gases it contains. Normally the earth emits back into space the same amount of radiation that it receives from the sun, however, with the levels of greenhouse gases increasing some of the radiation that should leave to keep the temperature on earth constant is being trapped (NOAA 2008). This trapping of heat is commonly called the greenhouse effect.

There are several different greenhouse gases, each with different levels of heat trapping potential. There are five main types of gases that cause the vast majority of the greenhouse effect: water vapor, carbon dioxide, methane, nitrous oxide, and fluorinated gases. Of these five, water vapor is the most abundant; however is it not directly affected globally by human activities.

Water Vapor

Water vapor is commonly known as clouds. Water vapor is the most abundant greenhouse gas on earth. Currently there is no accurate method of measuring water vapor concentrations in the atmosphere. Because of a lack of data and precise measurements on how much water vapor is in the atmosphere it is not commonly included as an anthropogenic greenhouse gas. Using a non-precise data measurement such as satellite pictures of earth scientists have determined that water vapor concentrations have generally been increasing (NOAA 2008). Even if precise data is not available to determine if water vapor concentrations are increasing as a direct result of human activity there are indirect factors that affect the quantity of gas. An indirect result of anthropogenic greenhouse gases is that this causes the earth's atmosphere to become warmer, and warmer air can hold more water vapor. So indirectly, as humans produce more greenhouse gases water vapor will also contribute an unknown amount to global warming. Scientists are currently working to develop better ways to monitor concentrations of water vapor.

Carbon Dioxide

Carbon dioxide is the main anthropogenic green house gas and is produced both naturally by normally functioning ecosystems and also by humans. In comparison the anthropogenic production of carbon dioxide are relatively small compared to the production in nature. The level of anthropogenic carbon dioxide produced is approximately 2 percent of the total produced on earth (EIA 2008c). The increase in production by humans is mainly caused by fossil fuel combustion, deforestation, and industrial processes. Fossil fuel combustion includes both stationary sources such as coal burning power plants, and mobile sources such as cars, planes, and trains. Deforestation causes increases in carbon dioxide because trees use carbon dioxide during photosynthesis to produce food and release oxygen. Permanently removing the trees removes one of the earth's balance systems. Before the industrial revolution in the mid 1700's the amount of carbon dioxide in the atmosphere was relatively stable at about 280 parts per million (NOAA 2008). With the discovery and heavy use of fossil fuels over the past 200 years the current level of carbon dioxide in the atmosphere is 384 ppm. Over millions of years the level of carbon dioxide remained stable at around 280 ppm and in only 250 years humans have increased the level by 37% (NOAA 2008).

Carbon dioxide levels regularly fluctuate with the change of seasons. The northern hemisphere contains more land and therefore more plant life. When the northern hemisphere transitions in fall and winter there is a rise in carbon dioxide due to the decomposing plants. In the spring and summer carbon dioxide levels fall as a result of new plant growth and photosynthesis.

Methane

Methane is another greenhouse gas that is produced both by human activity and occurs naturally in nature (NOAA 2008). Methane is less common in the atmosphere when compared to carbon dioxide but it traps heat much better. Methane is produced naturally by biological processes in swamps and other low oxygen environments. The releases of natural methane occur more rapidly when land is drained. Anthropogenic causes of methane production are raising agriculture, mining and burning fossil fuels, and landfills with organic human waste. Methane is formed in landfills and by large cattle farms when the trash and excrement decomposes. Methane concentrations have risen from 700 parts per billion in the pre-industrial revolution to 1,770 parts per billion currently (NOAA 2008), an increase of 150% over 250 years.

Nitrous Oxide

Nitrous oxide is produced naturally in the environment by microorganisms in the soil. Nitrous oxide is also produced by humans during farming operations using nitrogen fertilizer and also by some industrial processes which include the burning of fossil fuels for power generation, vehicle emissions, and the combustion and disposal of solid waste. Before the industrial revolution levels of nitrous oxide were at 270 parts per billion, current levels have risen 44 parts per billion to 314 parts per billion or 16% (NOAA 2008).

Fluorinated Gases

Fluorinated gases are synthetic gases created by humans used for refrigerants, aerosol propellants, and many other industrial uses since 1928. These gases are not found in nature. Many of these gases have been banned in developed countries because it was discovered that they deplete the ozone layer. These gases are found in much smaller quantities than the 4 other major greenhouse gases, but their global warming potential is significantly more. Fluorinated gases have global warming potentials that normally fall between 1,500 and 25,000 and have lifespan of between 12 and 50,000 years (EPA 2002). Due to their long atmospheric lifespan and high GWP only a small amount of fluorinated gases can have the same effect as a vast amount of carbon dioxide which has a GWP of 1. In the United States hydroflourcarbons like HCFC-22 which has a lifespan of 12.1 years will be phased out in the year 2030 (EPA 2009d).

Global Warming Potential

When comparing different greenhouse gasses, the term Global Warming Potential (GWP) is used and allows various policy makers to compare the impacts of emissions and reductions of different greenhouse gasses (EPA 2002). GWP is a quantified measure of the globally averaged radiative forcing impacts of a particular greenhouse gas (EPA 2002). Radiative forcing as defined by the Intergovernmental Panel on Climate Change (IPCC) is "…a measure of how the energy balance of the Earth-atmosphere system is influenced when factors that affect climate are altered" (IPCC 2009). Another definition of GWP as defined by the Encyclopedia of Earth is "A measure of the influence that a climatic factor has in altering the balance of incoming and outgoing energy in the Earth-atmosphere system. Also used as an index of the influence a factor has as a potential climate change mechanism" (Encyclopedia of Earth 2007).

Global warming potentials are defined as a definite number for each gas but due to a number of uncertainties in the formula they are estimated to vary by as much as 35% from the defined value (EPA 2002). GWP values for gases vary depending on the age of the gas because as certain gases age, they degrade and their radiative forcing decreases. The base used for GWP is carbon dioxide, meaning that carbon dioxide has a GWP of 1 at all times. The common practice is to convert all global warming gases into their carbon dioxide equivalent so that the amounts of each gas can be accurately compared using one scale. Refer to Table 2-1 for GHG GWP values.

History of Greenhouse Gas Levels

Greenhouse gas levels have fluctuated over the earth's lifetime but have remained relatively stable in the past 10,000 years. Scientists use ice core samples from all over the world to determine the level of greenhouse gases at different time periods. These ice core samples give scientists data about GHG levels during different climate cycles. The ice contains small air bubbles and scientists use large drills to extract cores and then take samples of the air bubbles to measure GHG levels. The deeper the ice bubbles are, the older the air inside of them is. Currently scientists are ice coring in large ice caps in both Antarctica and Greenland. A project in Antarctica has now drilled to a level of ice that is 240,000 thousands years old (ESF 2009). . These ice cores will provide crucial information about predicting future impacts of increases in GHG levels.

Over the past 250 years since the beginning of the industrial revolution GHG levels have been on the rise, consequently, temperatures on earth have also risen slightly as a result. According to the National Climate Data Center global surface temperatures have increased about 0.74°C since the beginning of the industrial revolution in 1750 (NOAA 2008). This rise in temperature on earth coincides with the introduction of mining and burning fossil fuels.

When looking over GHG emissions data the results for the same country tend to vary slightly depending on the publisher of the report. This is because the GHG emissions data are estimates as there are no exact measurements that can be done to determine the precise amount that was emitted at a countrywide or statewide level. Many agencies often come up with slightly different numbers depending on the data used. The United Nations Framework Convention on Climate Change (UNFCCC) has a standard reporting format and provides formulas so that countries all report using the same formulas and in the same format (UNFCC 2006). This provides for more comparable numbers inside the UNFCC country reports. However other reports such as the Navigating The Numbers report and the spreadsheet data published by the Energy Information Administration use slightly different techniques to estimate GHG emissions. This results in large differences between GHG emissions between reports depending on what is included in the calculations of GHG emissions.

"The United States' share of world emissions is estimated at 24 percent when counting only CO2 emissions from fossil fuel use, but drops to 21 percent when non-CO2 gases are added, and to 16 percent for all gases and land use change and forestry (LUCF) absorption (although the U.S. nevertheless ranks first in all three methods). Conversely, Indonesia, which ranks 21st in total emissions when only CO2 from fossil fuels is considered, ranks 4th when land use and non-CO2 gases are added (WRI 2005)." An overview of worldwide greenhouse gas emissions by country and data source is provided in Table 2-2.

Worldwide Greenhouse Gas Emissions

Kyoto Protocol

Due to concerns about global warming, countries met in December, 1999 in Kyoto Japan. These countries created goals and a contract that came to be known as the Kyoto Protocol. The Kyoto Protocol sets binding targets for 37 industrialized countries for reducing greenhouse gas emissions (UNFCCC 2009). The Protocol recognized that developed countries are mainly responsible for the current high levels of GHG concentrations because of their long term industrial activity and put the majority of the burden on them to reduce their GHG emissions. The Kyoto Protocol sets emissions goals for the six most impactful greenhouse gases: carbon dioxide, methane, nitrous oxide, hydroflourocarbons, perfluorcarbons, and sulphur hexafluoride (UNFCCC 2009). The goals varied by emission reductions of 8% to emission increases of 10% depending on the country. Collectively the Kyoto Protocol aims to reduce overall GHG emissions from industrialized countries by 5.2% from 1990 levels (UNFCCC 2009). As of 2005 nearly every country in the world had signed the Kyoto Protocol except for the United States.

China

China's population has risen to over 1 billion people or about 20 percent of the human population on earth. With this great population comes an enormous amount of greenhouse gas emissions. A 2004 report ranked second only behind the United States in GHG emissions with about 14.7% or 4,938 million metric tons of CO2 equivalent (WRI 2005). Also steady growth over the past 50 years in both population and economy has fueled a massive industrial revolution throughout China. From 1990 to 2002 China's GHG emissions grew by 49% or 1,247 million metric tons of CO2 equivalent (WRI 2005). China's emissions growth during that time period in terms of metric tons was 44% greater than the United States, which was the second fastest growing country. A recent 2008 Energy Information Administration (EIA) report concludes that China's 2006 GHG emissions were slightly higher than the United States, with a total 6,017.69 million metric tons of CO2 equivalent (EIA 2008b). That is approximately 115 million metric tons more than the United States.

In 1994 the Chinese government provided a report to the United Nation's Framework Convention on Climate Change (UNFCCC). This detailed report outlined how much GHG was being produced and the origins. The report concluded "the total amount of Greenhouse gases in China in 1994 was 3,650 million tons of carbon dioxide equivalent, of which carbon dioxide, methane, and nitrous oxide accounted for 73.05%, 19.73%, and 7.22% respectively" (Peoples Republic of China 2004). In China the Energy sector produces 90.95% of the total CO2 emissions while the rest comes from industrial processes like cement and lime production. Methane emissions were contributed by energy production and use (27.33%), agriculture (50.15%), and waste treatment (22.52%) (Peoples Republic of China 2004). Nitrous oxide emissions were contributed by agriculture (92.43%), Energy (5.82%), and industrial processes (1.75%).

Estimates are that China's future GHG emissions will increase rapidly. The 2005 WRI report estimates that from 2000 to 2025 China's GHG emissions will increase by 50% to 181% with a best estimate of 118% (WRI 2005). Using a 2008 Energy Information Administration's report of current and past data, China more than doubled its GHG emissions in only six years (EIA 2008b). With China's projected growth and considering they are still a "developing" country there is much opportunity in the short term to change the country's ways and methods to reduce the amount of GHG emissions.

Europe and the European Union

The European Union includes nearly every country in Europe. The EU is made up of long developed countries in which most have nearly no population growth. The European countries have been grouped together for the GHG emissions because many of them are significantly small in comparison to most large countries and because they all share the same region and development. Together the EU27's total countries land surface area is just under 50% of that of China's or the United States. A report published by the WRI in 2005 uses the abbreviation EU25, which includes 25 European countries. As of 2007 Bulgaria and Romania joined the EU which changed the EU25 to the EU27. In 2004 the EU25 is the third largest GHG emitter on the planet producing 4,725 million metric tons of CO2 or 14% of the world's total (WRI 2005).

Inside the EU25 the top 6 GHG producers are Germany (3%), United Kingdom (1.9%), Italy (1.6%), France (1.5%), Spain (1.1%), and Poland (1.1%). As compared to China, the United States, India, Japan and many other countries whose GHG emissions are on the rise, the EU25's GHG emissions have been declining. From 1990 to 2002 the EU25's GHG emissions fell 2% or 70 million metric tons (WRI 2005). Using the 2008 EIA report on GHG emissions for the periods 2000 to 2006, Germany showed no increase, the United Kingdom a 4.3% increase, Italy a 4% increase, France a 3.5% increase, Spain a 12% increase, and Poland a 2.7% increase (EIA 2008b). Overall the EIA report which includes more than just EU25 for Europe estimated a 3.3% increase in GHG emissions during the same period as the WRI estimated a 2% fall (EIA 2008b).

Using a 2008 European Environment Agency report that summarizes the EU27's GHG emissions the EU27 emitted 5,142.8 million metric tons of GHG. Of these emissions energy supply and use accounted for 60.4%, transport for 19.3%, industrial processes for 8.1%, agriculture for 9.2%, and waste for 2.9% (EEA 2008). Of the gasses emitted, 82.7% was CO2, 14.2% was CH4, 1.5% was fluorinated gases, and 0.6% was N2O (EEA 2008). Most members of the European Union are parties to the Kyoto Protocol, therefore they are trying to lower their GHG emissions (UNFCCC 2009). From 1990 to 2006 the EU27 has lowered its GHG emissions by 7.7% or 429.2 million metric tons (EEA 2008). In accomplishing the reduction the EU27 has lowered its waste emissions by 32%, agricultural emissions by 20%, industrial process emissions by 13%, and energy supply and use by 11% (EEA 2008). 2010 Projections for those four categories continue to show further reductions in GHG emissions (EEA 2008).

Russia

Russia is the forth largest GHG emitter in the world emitting 5.7% or 1,915 million metric tons of CO2 equivalent (WRI 2005). Russia is slightly larger than the United States in land surface area. Russia's GHG emissions are currently much smaller than they once were. According to the 2008 EIA report in 1991 after the fall of the Soviet Union, Russia's GHG emissions were 2,056 million metric tons compared to 2006's GHG emissions of 1,704 million metric tons (EIA 2008b). That's a reduction of over 300 million metric tons of GHG. Using the 2008 report submitted to the UNFCCC by the Russian government, Russia emitted 2,478 million metric tons of GHG (Russian Federation 2008). Of the emissions 72.1% was from energy use and production, 8% from industrial processes, 5.3% from agriculture, 11.6% from land use, land use change and forestry, and 2.95% from waste (Russian Federation 2008). Projections for Russia's growth is that from 2000 to 2025 Russia's GHG emissions will grow 42% (WRI 2005).

India

India is the fifth largest GHG emitter in the world emitting 5.6 % or 1,884 million metric tons of GHG (WRI 2005). Using the 2004 report from the Indian government to the UNFCCC India only produced 1,228 million metric tons of GHG. From 1980 to 2006 India's GHG emissions rose 442% and are still steadily rising (EIA 2008b). India's GHG emissions are 65% Carbon dioxide, 34% methane and 4% nitrous oxide. Of the emissions 61% is from energy use and production, 28% from agriculture, 8% from industrial processes, 2% from waste, and 1% from land use, land use change and forestry (Government of India 2008).

Japan

Japan is the 10th largest nation in the world in terms of population but the 6th in terms of GHG emissions. Japan emits 3.9% of the worlds GHG or 1,317 million metric tons of carbon dioxide equivalent (WRI 2005). However compared to other large countries in terms of GHG growth Japan falls in line with Russia. Japan's GHG emissions have only risen 5.8% over 16 years from 1990 to 2006 (EIA 2008b). Japan is a signatory of the Kyoto Protocol and is striving to meet a 6% reduction from 1990 level by 2012 (Government of Japan 2008). Japan's GHG emissions are unique from the other large emitting countries because nearly all of the countries emissions come from energy in the form of carbon dioxide. Of the GHG Japan emits 94.7% is carbon dioxide, 1.9% is from methane, 2.1% from nitrous oxide and another 1.4% from other GHG (Government of Japan 2008). Of the emissions 95.7% is from energy use and production, 5.8% from industrial processes, 0.02% from solvents, 2.2% from agriculture, -7.3% from land use change and forestry, and 3.6% from waste (Government of Japan 2008).

Brazil

Brazil is the largest country in South America with a land area of 3,287,660 square miles and a population of 170,000,000 people. Brazil is the 8th largest GHG producer emitting 851 million metric tons of carbon dioxide equivalent or 2.5% of the world's total (WRI 2005). Brazil has massive energy needs like most other developing countries, but unlike most countries the majority of Brazil's energy production does not come from fossil fuels. Brazil has massive waterways that provide the country with tremendous amounts of renewable energy (Government of Brazil 2008). In 1994, 95% of Brazil's power was provided by hydroelectric plants and 60% of its energy matrix was supplied by renewable resources (Government of Brazil 2008). When considering only fossil fuel GHG emissions for the same year the emissions drop from 851 to 344 million metric tons. When land use change and forestry are not considered the number falls to less than one half of that when it is included. This is because Brazil has a massive forestry industry and half of Brazil is covered by the Amazon rain forest. In a 1994 Brazil report to the UNFCCC land use change and forestry accounted for 75% of the countries total GHG emissions (Government of Brazil 2008). Another major contributor besides energy and land use change is Methane emissions from cattle excrement. Farmers and foresters cut and burn the rain forest to pave way for more cattle grazing lands. Brazil could easily reduce their GHG emissions by 75% by stopping the destruction of the rain forest.

Overall Average World Emissions

Each country has different GHG emissions depending on their location and their level of development. On average developed countries emissions are 81% from carbon dioxide directly related to fossil fuels, 11% from methane, 6% from nitrous oxide and 2% from fluorinated gases (WRI 2005). In developing countries the emissions contributions are split more evenly. On average in developing countries emissions are 41% from carbon dioxide directly related to fossil fuels, 33% from land use change and forestry, 16% from methane, and 10% from nitrous oxide (WRI 2005). In least developed countries there is almost no impact from fossil fuels and rather the impact is more from land use change and forestry. On average, in least developed countries emissions are 62% from land use change and forestry, 21% from methane, 12% from nitrous oxide, and 5% from fossil fuel use (WRI 2005). A current breakdown of the worldwide production of anthropogenic greenhouse gases by the World Resources Institute is located in Tables 2-3 and 2-4.

Greenhouse Gas Emissions in the United States

Since the beginning of the industrial revolution in the late 1700s the United States GHG emissions have risen tremendously. The United States is the overall leader in cumulative anthropogenic emissions from 1850 to 2002 with a cumulative 29.3% contribution (WRI 2005). Currently the United States has a population of 305,831,000 and is the largest GHG producer in the world with 6,170.5 million metric tons of carbon dioxide equivalent produced in 2006 (EPA 2009a). In addition the United States is the only developed country that chose not to ratify the Kyoto Protocol. The United States GHG emissions continue to grow with a growth rate of 1.4% from 2006 to 2007 (EPA 2009a). In 2002 the United States announced a new policy to lower the United States greenhouse gas intensity by 18% by the year 2012 (U.S. Department of State 2007). Greenhouse gas intensity measures the ratio of greenhouse gas emissions compared to economic output. This allows the economy to still grow while slowing down the growth rate for GHG emissions. If this goal is met, the U.S. will emit 7,709 million metric tons of GHG in 2012 and 8,330 million metric tons in 2020. If nothing is done to change the rate of growth, the U.S. GHG emissions would be 8,115 million metric tons in 2012 and 9,067 million metric tons in 2020 (U.S. Department of State 2007).

The United States is a developed country so it falls in line with many other developed countries with the majority of GHG being caused by fossil fuel consumption. Of the United States GHG emissions 84.8% is carbon dioxide, 7.9% methane, 5.2% nitrous oxide, and 2.1% fluorinated gases (EPA 2009a). Fossil fuel consumption is responsible for 94% of the total carbon dioxide emissions. The United Stated GHG emissions are 98.5% from energy use and production, 5.2% from industrial processes, 7.4% from agriculture, minus 13.7% from land use change and forestry, and 2.6% from waste (U.S. Department of State 2008).

Inside the United States GHG activities related to the construction industry cause emissions of all three major GHG gases: carbon dioxide, methane, and nitrous oxide. There are thousands of products and activities that cause GHG emissions related to construction. The major ones are: Iron and steel production, which emitted 49.1 million metric tons or 0.8% of the total of carbon dioxide (EPA 2009a); cement production, which emitted 45.7 million metric tons or 0.7% of the total carbon dioxide (EPA 2009a); municipal solid waste combustion (MSW), which includes both neighborhood waste and construction waste, which emitted 20.9 million metric tons of carbon dioxide (EPA 2009a); aluminum production, which emitted 3.9 million metric tons of carbon dioxide; titanium Dioxide, ferroalloy and zinc production, which emitted 1.9, 1.5, and 0.5 million metric tons of carbon dioxide (EPA 2009a); municipal solid waste landfills producing methane emitted another 125.7 million metric tons of carbon dioxide equivalent; iron and steel production also emitted methane equal to 0.9 million metric tons of carbon dioxide (EPA 2009a) and MSW combustion also contributed nitrous oxide equivalent to 0.4 million metric tons of carbon dioxide (EPA 2009a).

All together in 2006 waste combustion and landfilling accounted for 2.39% of the total GHG emissions in the United States (EPA 2009a). Of the landfill waste generated, 64% was from municipal solid waste landfills and the other 34% was from industrial landfills (EPA 1998a). Municipal solid waste generally refers to trash or garbage produced by neighborhoods and people during everyday activities. There are separate landfills for construction related debris and MSW, however a portion of landfill debris does end up in MSW landfills. According to a 1998 study by the US EPA approximately 30% to 40% of construction related debris ends up in MSW landfills (EPA 1998a). MSW landfills accounted for 88% of the emissions while the other 12% was from the industrial landfills (EPA 1998a). In the United States there are approximately 1,800 landfills (EPA 2009a) with each American producing an average of 4.6 pounds of MSW per day (EPA 2008). Also each American produces an average of 2.8 pounds of building related debris per day. In total that adds up to 251 million tons of MSW and 136 million tons of construction related debris. Of the actual construction related debris generally 40% to 50% is concrete and mixed rubble, 20% to 30% is wood, 5 to 15% is drywall, 1% to 10% is asphalt roofing, 1% to 5% is metals, 1% to 5% is bricks, and 1% to 5% is plastic (EPA 2009b). It is estimated of the total construction debris 57% comes from the commercial sector and 43% comes from the residential sector (EPA 2008). Also it is estimated that yearly 11 million tons or 8% of the debris is generated from new construction, 60 millions tons or 44% from renovation, and 65 million tons or 48% from demolition (EPA 2008).

Greenhouse Gas Emissions in Florida

Florida is the forth largest state by population with approximately 18 million residents and the 22nd largest state by land area containing 65,755 square miles. Florida's GHG emissions for 2004 were 289 million metric tons of carbon dioxide equivalent (FDEP 2007). Florida GHG emissions account for 4.66% of the United States GHG emissions total (FDEP 2007)). From 1990 to 2004 Florida's GHG emissions have risen at an average rate of 2.5% or a total of 80 million metric tons in 14 years. Of the gas emitted, 92% is carbon dioxide, 3% is methane, 3% is fluorinated gas, and 2% is nitrous oxide. Of the carbon dioxide emitted 49% is from electric utilities, 43% is from transportation, 5% from industrial, 2% from commercial, and 1% from residential (FDEP 2007).

In 2006 Florida produced 35,039,875 tons off MSW of which only 24% or 8,567,930 tons was recycled FDEP 2008). Of MSW produced 28.6% or 10,044,829 tons was construction and demolition debris (FDEP 2008). Overall in Florida in 2006 65% of the MSW was landfilled, 11% was combusted, and 24% recycled (FDEP 2008). Solid waste landfilling and combustion accounts for 10.11 million metric tons of carbon dioxide equivalent annually inside the state of Florida (FDEP 2007). Methane accounts for 5.482 million metric tons of carbon dioxide equivalent due to landfill emissions (FDEP 2007). Carbon dioxide accounts for 4.54 million metric tons due to plastic and synthetic material combustion (FDEP 2007). Due to waste combustion nitrous oxide accounts for 0.09 million metric tons of carbon dioxide equivalent (FDEP 2007).

Greenhouse Gas Emissions in Gainesville

The city of Gainesville is located in north central Florida in Alachua County and has a population of just over 95,000. The city is home to the University of Florida which accounts for about 60% of the population in the city. The city of Gainesville owns and operates Gainesville

Regional Utilities Company (GRU) which is the city power, water, and sewer provider. GRU is a non profit utility provider which strives to keep utility costs down and promotes green energy. Gainesville is a member of the U.S. Conference of Mayors which is an organization that seeks "to provide mayors with the guidance and assistance they need to lead their cities' efforts to reduce the greenhouse gas emissions that are linked to climate change" (The United States Conference of Mayors 2009). The city of Gainesville seeks to lower their GHG emissions. At a citywide level the author could not locate any complete emissions data.

The only data that could be located concerning GHG emissions at a citywide level is an annual report published by GRU. The report summarizes GRU's GHG emissions due to power production. The report does not include emissions from cars, waste, and other emissions producing activities, only power production. The GRU report concludes that Gainesville's power production related GHG emissions for 2007 were 1,991,760 metric tons of carbon dioxide equivalent (GRU 2008). The 2007 emissions are only 3.4% higher than 1990 emissions. GRU is trying to reach the Kyoto Protocol targets set which would mean a GHG emission reduction of 7% below 1990 levels. GRU predicts that by the year 2013, which is a year behind schedule, GRU will meet the Kyoto protocol's target reduction (GRU 2008).

Other GHG emissions in Gainesville to consider are from transportation, industrial processes and waste production. Citywide waste production levels could not be located, only countywide. Alachua County produced 284,614 tons of MSW, recycling only 22% while landfilling the remaining 78% (FDEP 2008). Of the 284,614 tons produced 25% was construction and demolition debris which has a recycling rate of zero when included in the MSW stream (FDEP 2008). That means that in Alachua county alone 70,982 tons of construction and demolition debris was landfilled.

Greenhouse Gas Emissions at the University of Florida

The University of Florida is located on 1,966 acres in central Gainesville. The university has approximately 45,000 students, 12,000 employees and 17,436,606 square feet of building area. The University of Florida must use its land wisely because it is surrounded on all sides by city. The university recognizes this issue and has adopted the policy of developing sustainably. The Office of Sustainability at UF was created to promote sustainability across campus. Also the University has a goal to become carbon neutral by 2025 (UF 2009). To further become sustainable UF has a policy that all future buildings will strive for a LEED Gold rating (UF 2009). This policy will help the university lower its overall carbon footprint.

Complete data for GHG emissions at UF could not be located. The only GHG emissions data that was located was data produced by the UF Office of Sustainability in 2006. The data only included GHG emissions from fossil fuel use related to University functions. The report concluded that in 2006 342,417 gallons of gasoline, 65,927 gallons of diesel, 62,138 gallons of jet fuel, 470,000,000 kWh of energy, 692,509,000 lbs of steam, 869,444,000 gallons of water, and 1,963,011 therms of natural gas were consumed at the university (UF 2007). The consumption of these materials produced 295,000 metric tons of carbon dioxide (UF 2007).

Because the university has a commitment to producing all future buildings to reach a LEED Gold rating contractors have had to begin construction recycling programs for UF construction projects. This data on construction waste recycling and diversion at 11 UF projects was used to calculate GHG emissions rates.

Table 2-1. Global warming potentials

Gas	Atmospheric lifetime (years)	100 year GWP	20 year GWP	500 year GWP
Carbon dioxide	50-200	1	1	1
Methane	9-15	21	56	6.5
Nitrous oxide	120	310	280	170
Hydroflourcarbons	1.5-264	140-11,700	460-9,100	42-9,800

(EPA 2002)

Table 2-2. Worldwide greenhouse gas emissions by country and data source

Source	WRI 2005		EIA 2008b		UNFCCC 2005, UNFCCC 2008	
Source Data	All emissions excluding international bunker fuels and land use change and forestry		World carbon dioxide emissions from the consumption and flaring of fossil fuels		Total aggregate anthropogenic emissions excluding emissions/removals from land use, land-use change and forestry	
Country	MtCO2 equivilent	% of worlds GHGs	MtCO2 equivilent	% of worlds GHGs	MtCO2 equivilent	% of worlds GHGs
United States	6,928	20.6%	5,902.75	20.2%	7,017	20.7%
China	4,938	14.7%	6,017.69	20.6%	4,057	12.0%
EU25	4,725	14.0%				
Russia	1,915	5.7%	1,704.36	5.8%	2,190	6.5%
India	1,884	5.6%	1,293.17	4.4%	1,214	3.6%
Japan	1,317	3.9%	1,246.76	4.3%	1,340	4.0%
Germany	1,009	3.0%	857.60	2.9%	1,005	3.0%
Brazil	851	2.5%	377.24	1.3%	659	1.9%
Canada	680	2.0%	614.33	2.1%	721	2.1%
United Kingdom	654	1.9%	585.71	2.0%	656	1.9%
Italy	531	1.6%	468.19	1.6%	568	1.7%
South Korea	521	1.5%	514.53	1.8%		
France	513	1.5%	417.75	1.4%	547	1.6%
Mexico	512	1.5%	435.60	1.5%	383	1.1%
Indonesia	503	1.5%	280.36	1.0%	323	1.0%
Australia	491	1.5%	417.06	1.4%	536	1.6%
Ukraine	482	1.4%	328.72	1.1%	443	1.3%
Iran	480	1.4%	471.48	1.6%	385	1.1%
South Africa	417	1.2%	443.58	1.5%	380	1.1%
Spain	381	1.1%	372.62	1.3%	433	1.3%
Poland	381	1.1%	303.42	1.0%	400	1.2%
Turkey	355	1.1%	235.70	0.8%	332	1.0%
Saudi Arabia	341	1.0%	424.08	1.5%		
Argentina	289	0.9%	162.19	0.6%	264	0.8%
Pakistan	285	0.8%	125.59	0.4%	161	0.5%
Listed countries	27,915	82.9%	24,001	82.2%	24,014	70.8%
Rest of world	5,751	17.1%	5,194	17.8%	9,891	29.2%
Total	33,666		29,195		33,905	

Table 2-3. Sources of worldwide production of anthropogenic greenhouse gases

Category	Percentage	Subcategory	Percentage
Energy production and Energy use	61.40%		
		Transportation	13.50%
		Electricity and heating	24.60%
		Other fuel consumption	9.00%
		Industry	10.40%
		Fugitive emissions	3.90%
Industrial processes	3.40%		
Land use change	18.20%		
		Deforestation	18.30%
		Afforestation	-1.50%
		Reforestation	-0.50%
		Harvest/management	2.50%
		Other	-0.60%
Agriculture	13.50%		
		Agriculture soils	6.00%
		Livestock and manure	5.10%
		Rice cultivation	1.50%
		Other agriculture	0.90%
Waste	3.60%		
		Landfills	2.00%
		Wastewater, other waste	1.60%

Table 2-4. Worldwide anthropogenic greenhouse gas breakdown by gas

Gas	Percentage
Carbon dioxide	77%
Methane	14%
Nitrous oxide	8%
Fluorinated gases	1%

CHAPTER 3
METHODOLOGY

Waste production and disposal data was collected at Leadership in Energy and Environmental Design (LEED) projects at the University of Florida. The total amount in tons for each material diverted, the location to where it was diverted, and the end use after diversion was found on the LEED waste management worksheets submitted to the United States Green Building Council (USGBC) and the University of Florida. The tons for each material diverted from the landfill were then converted into greenhouse gas emissions savings using the United States Environmental Protection Agency's (EPA) Waste Reduction Model (WARM).

Data Collected

The data collected for the 11 UF projects was retrieved from the LEED Materials and Resources Credit 2.1-2.2 construction waste management worksheets submitted to LEED online. Copies of the worksheets were made available through the UF Facilities and Planning Office, which retains records of all LEED points for all UF related construction projects. The data was collected and submitted by the general contractor which varies from project to project. The general contractors included Turner Construction, Perry Construction, Skanska, PPI, Whiting Turner, Ajax Building Corporation, and Centex Rooney Construction Company. With each of these general contractors came a different waste diversion reporting method. Some methods included long spreadsheets that listed every material and its weight while other just gave a general summary. The data was collected at the following UF construction projects: Law Information center, Harn Cofrin Pavilion,Vet Farm, Library West, Maguire Center, Nanofabrication Facility, Orthapedic Surgery and Sports Medicine Institute, Powell Center, Pugh Hall, Rinker Hall, and the Southside Stadium Renovation. The data was grouped into 12 major categories: Concrete, metals, asphalt, brick and block, wood, office recyclables, carpet, land clearing debris, sub-base, comingled debris, ceiling tile, and drywall. Once the data was grouped the conversion into GHG's emissions could be made.

WARM

The Waste Reduction Model (WARM), developed by the United States Environmental Protection Agency (EPA 2009c), was used to estimate GHG emissions from construction waste management. WARM was created to help solid waste planners track the GHG emissions reductions from different waste management practices. WARM calculates total GHG emissions reductions in either metric tons of carbon equivalent or metric tons of carbon dioxide equivalent from source reduction, recycling, combustion, composting, and landfilling. Every year WARM is updated and revised with the latest GHG data and when available new materials are added. The first version of WARM was released in 1998 and the latest version is WARM version 9 which was released in August 2008. The first version of WARM contained factors for 17 material types and the latest version contains 34 materials and many more options. A few examples of these newer options include defining transportation distances to the different waste management scenarios, selecting whether your local landfill captures methane gas, and the option to select if you would like to see the results in metric tons of carbon of metric tons of carbon dioxide equivalent.

WARM calculates GHG emissions reductions by allowing a user to create a baseline scenario and an alternative scenario. In most cases the baseline scenario is that waste is landfilled. The four alternate scenarios include source reduction, recycling, combustion, and composting. WARM considers 5 factors in the life cycle impacts of GHG emissions for each material in the program.

"(1) Energy consumption (specifically, combustion of fossil fuels) associated with making, transporting, using, and disposing the product or material that becomes a waste.

(2) Nonenergy-related manufacturing emissions, such as the CO_2 released when limestone is converted to lime

(3) CH_4 emissions from landfills where the waste is disposed.

(4) CO_2 and nitrous oxide (N_2O) emissions from waste combustion.

(5) Carbon sequestration, which refers to natural or manmade processes that remove carbon from the atmosphere and store it for long periods or permanently." (EPA 2006a)

Using the five factors listed above the EPA goes through certain steps in order to calculate the material's GHG emissions. The steps are similar for each material, however some materials require more steps because there are more factors to include. For example, paper relates to four of the five factors and has a GHG emission related to each where as concrete cannot be combusted, it does not emit methane gas in a landfill, and does not qualify for carbon sequestration. The only factors to be considered for concrete are process energy and transportation energy required to create virgin material versus recycled material. The GHG emissions factor calculations for both concrete and office paper will be explained below so that the complete process can be understood.

Concrete Example

Concrete is recycled by being crushed into aggregate and reused in the production of new concrete. This process saves the energy needed to mine and process virgin aggregate. Also normally virgin aggregate has to be transported further than recycled aggregate because mining locations are not as widespread as concrete plant locations. The first step in calculating overall emissions is to calculate the emissions of one ton of virgin aggregate. For concrete this includes only process energy and transportation energy. Process energy is calculated in BTU's and the national averages used to mine and process aggregate are used. The process energy used to create virgin aggregate in BTU's is 3.16% gasoline, 60.42% distillate fuel, 5.68% residual fuel, 22.61% electricity, 1.4% coal, and 6.74% natural gas (EPA 2003). Each of these different fuels has a fuel specific carbon emissions coefficient that is multiplied times the percentage it comprises in the process to get process energy emissions. For example distillate fuel produces 0.0199 metric tons of carbon equivalent (MTCE) per million BTU and when multiplied times the 0.0293 million BTU's a total of .0006 metric tons of carbon equivalent are created per ton of virgin aggregate processed (EPA 2003). Methane emissions are also calculated for concrete but they are so small they are insignificant. Secondly transportation energy for virgin aggregate must be calculated. The transportation distance default used is 30 miles and the energy used to transport is 100% diesel fuel (EPA 2003). Diesel fuel is then multiplied times its fuel specific carbon coefficient of 0.0199 metric tons of carbon equivalent per million BTU. The total emissions from transportation based on 30 miles is 0.0037 MTCE/ton of aggregate (EPA 2003). Now the same process takes place for recycled aggregate. First the process energy, 50% diesel fuel and 50% electricity, is calculated and converted into 0.0006 MTCE/ton (EPA 2003). Then the transportation emissions are calculated using a 15 mile transportation distance using 100% of diesel fuel. The transportation emissions are 0.0019 MTCE/ton. Finally the emissions for processing and transporting virgin and recycled materials are compared to give the overall saving per ton which can be found in Table 3-1.

Office Paper Example

Office paper, unlike recycled concrete which only qualifies for three of the five emissions factors, qualifies for four of the five factors. Recycled office paper actually takes more process energy to recycle than it does to make virgin paper from trees. There is a net process energy emission of 0.06 MTCE/Ton of office paper recycled (EPA 1998b). The transportation emissions net zero because it is assumed an equal distance between virgin trees and recycled paper. Also the net process non-energy related emissions are zero from paper recycling. The main difference between virgin paper and recycled paper is that when paper is recycled trees are not cut down which increases forest sequestration. For recycled office paper forest sequestration equals -.83 MTCE/ton of recycled paper (EPA 2006a). Another difference between organic and non organic materials is that when landfilled organic materials will emit methane gas during decomposition. This means unlike concrete that will not decompose, paper will decompose and emit landfill gasses. Also other GHG are emitted when organic materials are incinerated. In our case the incineration factor does not apply because it is assumed the waste would have been landfilled. Any trees based materials all have a forest sequestration emissions factor and landfill methane emission factors. (EPA 2006a)

Material Greenhouse Gas Conversion Factors Derived from WARM

Concrete

Concrete has a direct GHG emissions factor in the program in the EPA program which assumes that recycled concrete is crushed and reused as aggregate in new concrete. The distance used in WARM for recycling was 1 mile which is the average distance to Florida Concrete Recycling from the center of campus. The distance used for landfilling was 16 miles, the average distance to the local landfill from the center of campus. The GHG emissions factor for landfilling concrete is 0.0378 metric tons of carbon dioxide equivalent (MTCO2E) per ton landfilled and for recycling it is a reduction of 0.0105 MTCO2E per ton recycled (Table 3-2).

Asphalt

When comparing asphalt to concrete in this study there are many similarities because concrete is being crushed into aggregate. Aggregate is used in both concrete and asphalt and the virgin process and transportation emissions apply to both as well. In fact asphalt even has one major advantage over the concrete in this application because asphalt is ground into aggregate regardless of whether it is being recycled or not. Concrete is not crushed back into aggregate when it is landfilled. This means that when compared to concrete asphalt will have higher GHG savings per ton because there is no additional process energy required. Recycled asphalt will have a total emissions factor -0.0027 MTCE/Ton or 28% higher than recycled concrete. The EPA factor for concrete multiplied times 1.28 will be used to convert asphalt into GHG emission savings. That does not take into account the further benefit of using recycled asphalt which is that recycled asphalt requires less bitumen to create new asphalt. The landfilling and recycling distances were left as their default values in WARM because the LEED submittal sheets did not list a location where the asphalt was taken for recycling.

Metal/Steel

Metal and steel recycled on the construction projects is very comparable to the steel cans emissions factor used by the EPA. Steel cans are crushed and shipped to recycling facilities which makes them much more comparable to construction waste. Also because most of the saving from emissions is due to the process energy and not the transportation the difference will be very minimal. Other metals factors that were used were copper wire, which one project separated out specifically, and mixed metals which a project called inferior metals compared to structural steel members. Mixed metals are assumed to be 71% steel and 29% aluminum in the WARM program. The distances were left as default in WARM because the metals were all taken to various different metal recyclers around the city. The GHG emissions factor for landfilling of steel, copper and mixed metal is 0.0378 MTCO2E per ton landfilled. The GHG emissions factors, per ton of material recycled, for recycling steel, copper wire, and mixed metals are reductions of 1.80 MTCO2E, 4.97 MTCO2E, and 5.26 MTCO2E.

Brick/Block

The concrete block and brick recycled on the 11 LEED projects at UF was taken to Florida Concrete Recycling on Depot Street less than two miles from the center of campus. The block and brick was recycled into aggregate and reused in the making of new concrete. The EPA GHG emissions factor for concrete will be applied. The distances to the landfilling and recycling facilities used in WARM for brick and block were the same as for concrete. The GHG emissions factor for landfilling brick and block is 0.0378 MTCO2E per ton landfilled and for recycling it is a reduction of 0.0105 MTCO2E per ton recycled.

Wood

The wood recycled on the projects was a combination of both dimensional lumber and plywood. Both plywood and dimensional lumber are recycled into plywood and OSB. The EPA GHG emissions factor for Dimensional Lumber was applied to all recycled wood. The distances in WARM were left as default because the projects did not specify the location of the recycler. The GHG emissions factor for landfilling wood is 0.07 MTCO2E per ton landfilled and for recycling it is a reduction of 2.46 MTCO2E per ton recycled.

Office Recyclables

Office recyclables included paper, packing cardboard, plastic and aluminum cans recycled at the 11 construction projects. All of these materials have direct EPA emissions factors that match them. Office paper was used for all paper, mixed recyclables was used for plastic and aluminum, and corrugated cardboard was used for all cardboard. The default distances in WARM were used. The GHG emissions factors for landfilling of office paper, cardboard, and mixed recyclables, per ton landfilled, are 3.71 MTCO2E, 1.49 MTCO2E, and 0.93 MTCO2E. The GHG emissions factors, per ton of material recycled, for recycling office paper, cardboard, and mixed recyclables are reductions of 2.85 MTCO2E, 3.11 MTCO2E, and 2.89 MTCO2E.

Carpet

The EPA's emission factor for recycled carpet was used. The default distances in WARM were used. The GHG emissions factor for landfilling carpet is 0.04 MTCO2E per ton landfilled and for recycling it is a reduction of 7.24 MTCO2E per ton recycled.

Land Clearing Debris

Land clearing debris occurred at many of the different 11 LEED projects at UF. The debris were treated differently depending on what waste management practice that was selected. For the Law Info Center 26 tons of timber was taken to then mill for processing into dimensional lumber. The emissions factor in this case was selected to be landfilling of branches and the recycling emissions factor was selected to be recycled dimensional lumber. In many projects land clearing debris were taken to a local facility and other UF sites for composting. The EPA emissions factor used was landfilling of branches versus composting of branches. For another project trees were used as pulpwood versus taken to the landfill. The closest EPA emissions factor was the landfilling of branches versus the recycling of office paper. The distance used in WARM for landfilling and recycling was left as default, both being equal, because there are so many different scenarios that happened with the land clearing debris. The GHG emissions factors for paper and dimensional lumber are listed above. The GHG emissions factor for landfilling land clearing debris is 0.07 MTCO2E per ton landfilled and for composting it is a reduction of 0.20 MTCO2E per ton recycled.

Sub-Base

The sub-base that was recycled on projects was mainly limestone beneath asphalt parking lots and was recycled either onsite where prescribed fill was needed or onto another local jobsite. The closest EPA emissions factor for sub-base was recycled concrete because the virgin material in concrete is aggregate. The distance used for landfilling sub-base was 16 miles and the distance used for recycling was 1 mile because all sub-base was reused onsite or locally on a surrounding UF project. The GHG emissions factor for landfilling sub-base is 0.0378 MTCO2E per ton landfilled and for recycling it is a reduction of 0.0105 MTCO2E per ton recycled.

Drywall

Drywall is recycled by being ground up and then spread as a soil amendment agent. There is no major GHG benefit to diverting drywall from landfill compared to grinding it up and spreading it on land. The GHG emissions factor used for diverted drywall is 0.

Commingled Debris

Commingled debris occurred at only 1 project jobsite during demolition of an existing building for the Law Information Center. The commingled waste on this single project represents approximately 25% of the overall diverted waste on the 11 projects. The Law Information Center project produced nearly 15,000 tons of demolition and construction debris. Of this 15,000 tons, 6,065 tons was not separated out on the jobsite and was taken as commingled debris to Florence Waste Recycling and Landfill off of Hawthorne road. The demolition contractor listed that 100% of the commingled debris was diverted from the landfill however upon speaking with the landfill this is highly unlikely. The Florence waste facility only recycles steel, aluminum, concrete, and untreated wood. The phone operator said the majority of waste received is landfilled. This being the case, the author believes that is highly unlikely 100% of comingled waste from the law project was diverted from the landfill and instead that the vast majority of the waste actually ended up being landfilled. The comingled waste listed on the LEED submittal form will not be left in the project study because there is no way to determine the GHG emissions reductions.

Ceiling Tile

Ceiling tile was recycled at only 1 UF project, Library West renovation and expansion, and accounted for 43 tons of diverted material. Unlike the majority of all other construction materials that were diverted, the Waste Reduction Model does not include anything that is comparable to ceiling tile. The closest emissions savings factor that could be located for ceiling tile was a number produced by Armstrong, a ceiling tile manufacturer. Armstrong lists on their website that for every 1 ton of ceiling tile recycled, 0.458 metric tons of carbon dioxide equivalent emissions are avoided (Armstrong, 2009).

Limitations

One major problem that occurred during the gathering of data was the problem with the comingled waste data. The comingled waste was not described in enough detail and the backup material provided was not helpful either. The comingled waste accounted for roughly 25% of the diverted waste material however it was removed from the study upon realizing that there was no way to discover what materials were included in the comingled waste. The author recommends to the University of Florida that a uniform reporting format be created and given to contractors so that all waste diversion data is reported using one format. This format should break out each material, where the material was taken for recycling, how far away that the recycling facility is, how much the material weighs, in tons, and if the waste was generated during new construction activities or during demolition.

Other limitations included inaccurate weight estimates or material breakdowns on the LEED submittal sheets provided to the USGBC and the University of Florida. For some projects weights were rounded to the nearest thousand pounds for each waste ticket submitted. This caused material weights to have some uncertainty and error. On certain projects, assumptions were made about distances to the landfill and waste diversion facilities because it was not stated on the submittal sheet. There were also limitations when using the WARM analysis tool because there are assumptions and approximations made inside the tool that do not always match the local environment. The tool is based on national averages and distances which limits the overall accuracy when used at the local level.

Table 3-1. Aggregate recycling emission factors

	A Process energy emissions	B Transportation energy emissions	A+B Total
Recycled manufacture	0.0006	0.0019	0.0025
Virgin manufacture	0.0009	0.0037	0.0046
Total (recycled- virgin)	-0.0003	-0.0018	-0.0021

Table 3-2. Per ton estimates of greenhouse gas emissions for alternative management scenarios

Material	GHG emissions per ton of material recycled (MTCO2E)	GHG emissions per ton of material landfilled (MTCO2E)	GHG emissions per ton of material composted (MTCO2E)
Steel cans	(1.80)	0.04	NA
Copper wire	(4.97)	0.04	NA
Corrugated cardboard	(3.11)	1.49	NA
Office paper	(2.85)	3.71	NA
Dimensional lumber	(2.46)	0.07	NA
Branches	NA	0.07	(0.20)
Mixed paper, broad	(3.54)	1.35	NA
Mixed metals	(5.26)	0.04	NA
Mixed recyclables	(2.89)	0.93	NA
Carpet	(7.24)	0.04	NA
Concrete/ brick/ block (EPA 2009c)	(0.0105)	0.0378	NA
Ceiling tile (Armstrong, 2009)	-0.456		

CHAPTER 4
RESULTS

Overall Summary

On the 11 UF LEED projects that data was gathered from the total amount of waste was 23,690 tons with 18,124 tons being diverted and the remaining 5,566 tons being landfilled (Table 4-12). The waste diversion rate across the 11 projects in the study was 76.5%. The material that accounted for the most recycled weight was concrete with 11,549 tons (Table 4-13). In order after concrete was sub-base with 2,198 tons, brick and block with 1,257 tons, land clearing debris with 1,052 tons, metals with 836 tons, asphalt with 780 tons, drywall with 156 tons, wood with 134 tons, carpet with 64 tons, office recyclables with 56 tons, and ceiling tile with 43 tons. Once converted the data shows that all together the 11 projects reduced GHG emissions by 3,642 metric tons of carbon dioxide equivalent through the implementation of LEED recycling programs.

Emission Reductions by Project

The single largest contributor by project was Library West which contributed 39.9% of the emissions reductions while only producing 12.6% of the total diverted waste (Table 4-14). This large difference is caused because the project recycled 3 high emissions reducing materials; carpet wood and steel. These 3 materials on this project accounted for 35.6% of the overall emissions savings across the entire 11 projects. The second largest contributor by project was the Law Info Center which contributed 18.4% of the emissions reductions while producing 37.7% of the total diverted waste. This correlation is not surprising because of the large amount of concrete that was diverted on the project, 6,386 tons. The third largest contributor by project was the Vet Farm which contributed 17.3% of the overall emissions savings while producing only 7.96% of the diverted waste. The Vet Farm's emissions savings come primarily from steel with minor contribution from cardboard and concrete. The forth largest contributor by project was the Nanoscience Institute which accounted for 10% of the overall emissions savings while producing 6.8% of the diverted waste. The majority of emissions savings on this project were achieved by composting land clearing debris with minor contributions from diverting dimensional lumber and steel.

These four projects alone accounted for 85.6% of the total emissions savings across the 11 projects. The 7 remaining projects accounted for the final 14.4% of total emissions while producing 30.7% of the total waste diverted in tons.

Emissions Reductions by Material

The correlation between materials and their emission factors had a large impact. The material with the largest impact on emissions reductions was metal which accounted for 4.6% of the diverted waste by mass, but represented 42.3% of the emissions reductions (Table 4-13). The material with the second largest impact on emissions reductions was concrete which accounted for 63.7% of the total waste diverted while representing 15.3% of the emissions reductions. The material with the third largest impact on emissions was carpet which accounted for 0.4% of the total waste diverted while representing 12.7% of the total emissions reductions. The materials\ with the forth largest impact on emissions was wood which accounted for 0.7% of the total waste diverted while representing 9.3% of the emissions reductions. Land clearing debris was fifth in overall emissions reductions at 9.1% while contributing 5.8% of the total waste. The 6 remaining materials contributed 24.5% of the waste diverted but only 11.3% of the emissions reductions.

Emissions Reductions per Square Foot

Once the emissions reductions were calculated, the gross square footages for the buildings were used to calculate an emission reduction by square foot per project and overall. The overall average for emissions reductions by square foot for all 11 UF LEED projects was 0.0051 metric tons of carbon dioxide equivalent per square foot (Table 4-15).

The Vet Farm project had highest emission reduction per square foot 53 kg of carbon dioxide equivalent per square foot. This is due to the fact that the project included demolition on an existing mainly metal building and construction of a small building. The net result was a high emissions reduction per square foot. The project with the second highest emissions reduction per square foot was the Powell Center with 12 kg of carbon dioxide equivalent per square foot. The remainder of the buildings emissions reductions fell below 10 kg of carbon dioxide equivalent per square foot.

Emissions Reductions by Type of Construction

The 11 projects were broken into 2 categories, projects that consisted on new construction with very minor demolition that included sidewalks and parking lots, and projects that included major demolition of buildings and then new construction on the same site. The new construction category included 6 projects while the demolition and new construction category included 5 projects. Buildings in the demolition and new construction category represented 82.3% of the emissions reductions while projects in the new construction category represented the remaining 17.7% of the emissions reductions (Figure 4-5).

Once broken down into categories, the difference between project types is very evident. The six projects that include only new construction average 1.87 kg of carbon dioxide equivalent per square foot while the projects that include demolition average 8.10 kg of carbon dioxide equivalent (Figure 4-6).

Table 4-1. Law Info Center waste diverted and greenhouse gas conversion

Material	Tons diverted	GHG emissions for material landfilled (MTCO2E)	GHG emissions for material recycled or composted (MTCO2E)	Total GHG emissions savings (MTCO2E)
Concrete	6,386	241.57	(67.17)	309
Asphalt	110	4.16	(1.49)	6
Steel	154	5.85	(277.01)	283
Limerock	170	6.43	(1.79)	8
Trees to Mill	26	1.90	(63.90)	66
Comingled Debris	0			-
Total	6,846			671

Table 4-2. Harn Cofrin Pavilion waste diverted and greenhouse gas conversion

Material	Tons diverted	GHG emissions for material landfilled (MTCO2E)	GHG emissions for material recycled or composted (MTCO2E)	Total GHG emissions savings (MTCO2E)
Concrete	320	12.10	(3.37)	16
Cardboard	2	1.49	(7.63)	9
Paper	0.4	1.49	(1.14)	3
Plastic and Aluminum	0.06	0.06	(0.17)	0.2
Copper	0.338	0.01	(1.68)	2
Total	323			29

Table 4-3. UF Vet Farm waste diverted and greenhouse gas conversion

Material	Tons diverted	GHG emissions for material landfilled (MTCO2E)	GHG emissions for material recycled or composted (MTCO2E)	Total ghg emissions savings (MTCO2E)
Concrete	1,140	43.12	(11.99)	55
Paper and Cardboard	42	1.49	(131.85)	133
Asphalt	20	0.76	(0.27)	1
Steel	240	9.11	(431.71)	441
Total	1,442			630

Table 4-4. Library West waste diverted and greenhouse gas conversion

Material	Tons diverted	GHG emissions for material landfilled (MTCO2E)	GHG emissions for material recycled or composted (MTCO2E)	Total GHG emissions savings (MTCO2E)
Concrete	1247	47.18	(13.12)	60
Asphalt	180	6.81	(2.43)	9
Steel	318	12.09	(572.71)	585
Cardboard	5	1.49	-15.57	17
Wood / Lumber	98	7.14	(239.70)	247
CMU	799	30.23	(8.41)	39
Carpet	64	2.42	(460.56)	463
Ceiling Tile	43			19
Limerock	280	10.59	(2.95)	14
Ballast	3	0.09	(0.03)	0.1
Total	3036			1,453

Table 4-5. Maguire Center waste diverted and greenhouse gas conversion

Material	Tons diverted	GHG emissions for material landfilled (MTCO2E)	GHG emissions for material recycled or composted (MTCO2E)	Total GHG emissions savings (MTCO2E)
Concrete	48	1.82	(0.50)	2
Land Clearing / Tree Debris	150	10.97	-29.78	41
Tree and Stump (Pulpwood)	65	4.76	-13.57	18
Paper	0.45	1.67	-1.28	3
Plastic and Aluminum	0.075	0.069	-0.22	0.3
Total	264			64

Table 4-6. Nanotechnology Research Center waste diverted and greenhouse gas conversion

Material	Tons diverted	GHG emissions for material landfilled (MTCO2E)	GHG emissions for material recycled or composted (MTCO2E)	Total GHG emissions savings (MTCO2E)
Concrete	411	15.55	(4.32)	20
Cardboard	4.36	1.49	(13.57)	15
Land Clearing	736	53.85	-146.14	200
Steel	31	1.17	(55.56)	57
Red Brick	22	0.846	-0.24	1
Wood	28	2.06	(69.33)	71
Total	1233			364

Table 4-7. Orthopedic Center waste diverted and greenhouse gas conversion

Material	Tons diverted	GHG emissions for material landfilled (MTCO2E)	GHG emissions for material recycled or composted (MTCO2E)	Total GHG emissions savings (MTCO2E)
Concrete	18	0.68	(0.19)	1
Wood	8	0.59	(19.66)	20
Steel	34	1.29	(61.10)	62
Drywall	142			
Total	202			84

Table 4-8. Powell Center waste diverted and greenhouse gas conversion

Material	Tons diverted	GHG emissions for material landfilled (MTCO2E)	GHG emissions for material recycled or composted (MTCO2E)	Total GHG emissions savings (MTCO2E)
Concrete	245	9.27	(2.58)	12
Asphalt	240	9.08	(3.24)	12
Existing Fill Dirt	86	3.25	(0.90)	4
Removed Topsoil	1385	52.39	(14.57)	67
Steel	4	0.15	(7.20)	7
Total	1960			103

Table 4-9. Graham Center at Pugh Hall waste diverted and greenhouse gas conversion

Material	Tons diverted	GHG emissions for material landfilled (MTCO2E)	GHG emissions for material recycled or composted (MTCO2E)	Total GHG emissions savings (MTCO2E)
Concrete	455	17.21	(4.79)	22
Steel	11	0.42	(19.97)	20
Total	466			42

Table 4-10. Rinker Hall waste diverted and greenhouse gas conversion

Material	Tons diverted	GHG emissions for material landfilled (MTCO2E)	GHG emissions for material recycled or composted (MTCO2E)	Total GHG emissions savings (MTCO2E)
Concrete	479	18.12	(5.04)	23
Asphalt	230	8.70	(3.11)	12
Land clearing debris	75	5.49	(0.20)	6
limerock	274	10.36	(2.88)	13
Gypsum wallboard	14	-	-	-
Steel	2	0.08	(3.60)	4
Cardboard	1	1.49	(3.11)	5
Total	1075			62

Table 4-11. Southwest Stadium Expansion waste diverted and greenhouse gas conversion

Material	Tons diverted	GHG emissions for material landfilled (MTCO2E)	GHG emissions for material recycled or composted (MTCO2E)	Total GHG emissions savings (MTCO2E)
Concrete	800	30.25	(8.41)	39
Brick and Block	436	16.49	(4.59)	21
Steel	41	1.56	(73.97)	76
Mixed Metals	0.6	0.02	-3.16	3
Total	1277			138

Table 4-12. Overall waste production by project

Project	Total tons diverted	Total tons not diverted	Total tons of waste	Percentage of waste diverted
Law Info Center	6,846	1920	8,766	78.1%
Harn Cofrin Pavilion	323	140	463	69.8%
Vet Farm	1,442	880	2,322	62.1%
Library West	3,036	790	3,826	79.4%
Maguire	264	245	509	51.8%
Nano	1,233	182	1,415	87.1%
Orthapedic	202	146	348	58.0%
Powell	1,960	94	2,054	95.4%
Pugh Hall	466	580	1,046	44.6%
Rinker Hall	1,075	203	1,278	84.1%
Stadium	1,277	386	1,663	76.8%
Totals	18,124	5566	23,690	76.5%

Table 4-13. Overall totals by material

Total	Total tons	% of total tons	Total GHG savings (MTCO2E)	% of total GHG savings
Concrete	11,549	63.7%	558	15.3%
Metals	836	4.6%	1,539	42.3%
Asphalt	780	4.3%	40	1.1%
Brick and Block	1,257	6.9%	61	1.7%
Wood	134	0.7%	338	9.3%
Office Recyclables	56	0.3%	185	5.1%
Carpet	64	0.4%	463	12.7%
Land Clearing Debris	1,052	5.8%	331	9.1%
Sub-base	2,198	12.1%	106	2.9%
Comingled Debris	-	0.0%	0	0.00%
Ceiling Tile	43	0.2%	20	0.53%
Drywall	156	0.9%	0	0.00%
Totals	18,124		3,642	

Table 4-14. Overall totals by project

Project	Total tons diverted	% of total tons	GHG savings (MTCO2E)	% of total GHG savings
Law Info Center	6,846	37.77%	671	18.4%
Harn Cofrin Pavilion	323	1.78%	29	0.8%
Vet Farm	1,442	7.96%	630	17.3%
Library West	3,036	16.75%	1453	39.9%
Maguire	264	1.45%	64	1.8%
Nano	1,233	6.80%	364	10.0%
Orthapedic	202	1.11%	84	2.3%
Powell	1,960	10.81%	103	2.8%
Pugh Hall	466	2.57%	42	1.2%
Rinker Hall	1,075	5.93%	62	1.7%
Stadium	1,277	7.05%	138	3.8%
Totals	18,124		3,642	

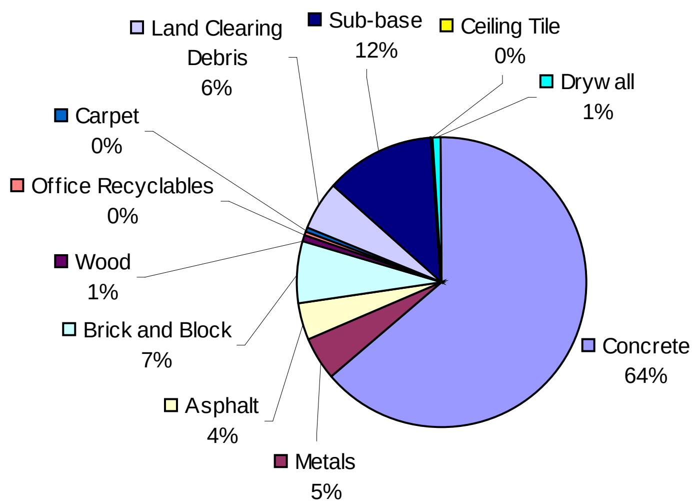

Figure 4-1. Total tons of diverted waste

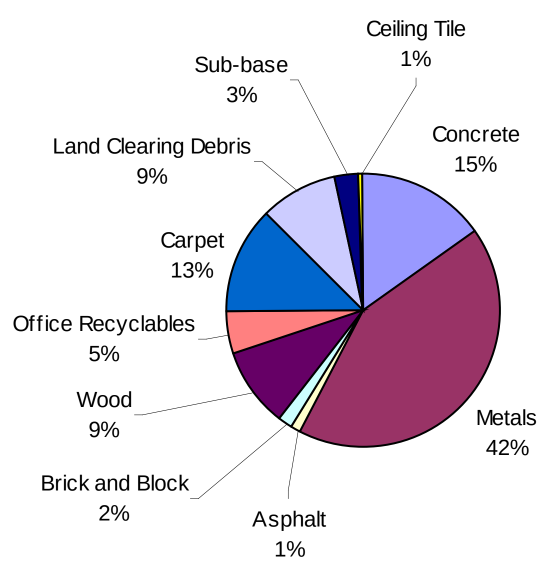

Figure 4-2. Material percentages of total greenhouse gas savings

Table 4-15. Greenhouse gas savings per square foot and type of construction

Building	Gross SF	GHG savings (MTCO2E)	% of total GHG savings across 11 UF LEED buildings	GHG savings per SF (KGCO2E)	GHG savings per ton of waste diverted (KGCO2E)	Type of construction
Law Info Center	105,500	671	18.4%	6.36	98.1	Demolition and new construction
Harn Cofrin Pavilion	19,240	29	0.8%	1.51	90.1	New construction
Vet Farm	11,900	630	17.3%	52.97	437.0	Demolition and new construction
Library West	177,000	1,453	39.9%	8.21	478.5	Demolition / renovation / addition
Maguire	58,000	64	1.8%	1.11	244.2	New construction
Nano	52,000	364	10.0%	7.00	295.4	New construction
Orthapedic	120,000	84	2.3%	0.70	413.5	New construction
Powell	8,565	103	2.8%	11.98	52.4	Demolition and new construction
Pugh Hall	48,617	42	1.2%	0.87	90.9	New construction
Rinker Hall	46,530	62	1.7%	1.34	57.8	New construction
Stadium	66,650	138	3.8%	2.08	108.4	Demolition / addition
Total for all 11 Buildings	714,002	3642	100%	5.10	215.1	All types
Projects With Demolition	369,615	2,995	82.3%	8.10	234.9	Projects involving demolition
Projects that are New Construction	344,387	646	17.7%	1.87	198.7	New construction only

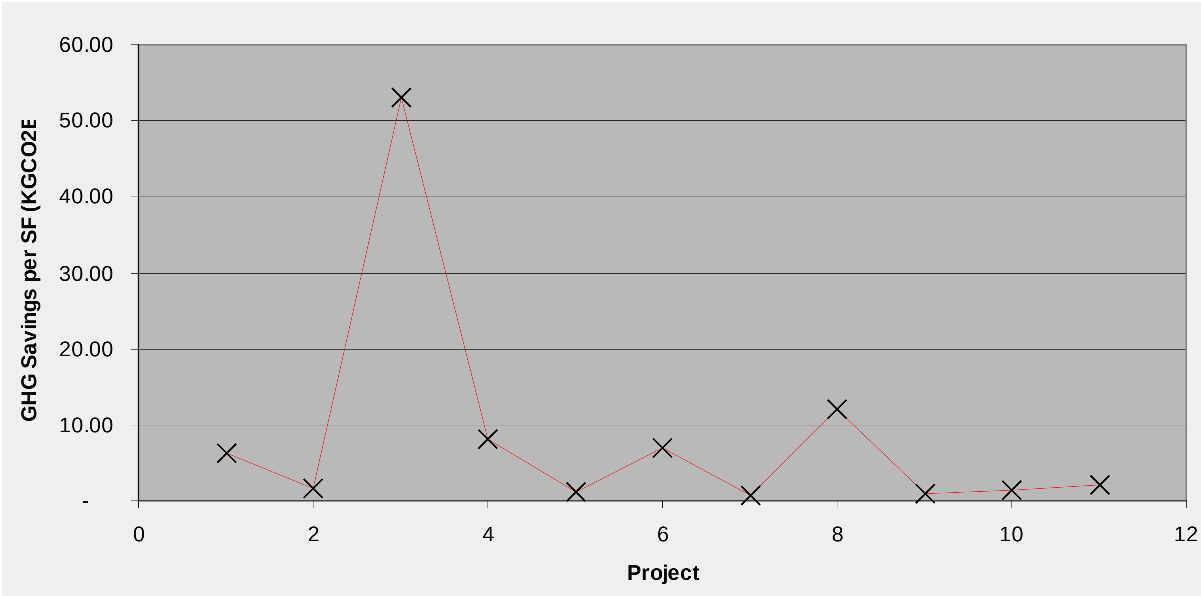

Figure 4-3. Greenhouse gas savings per square foot. Projects 1, 3, 4, 8 and 11 include demolition; projects 2, 5, 6, 7, 9 and 10 include only new construction.

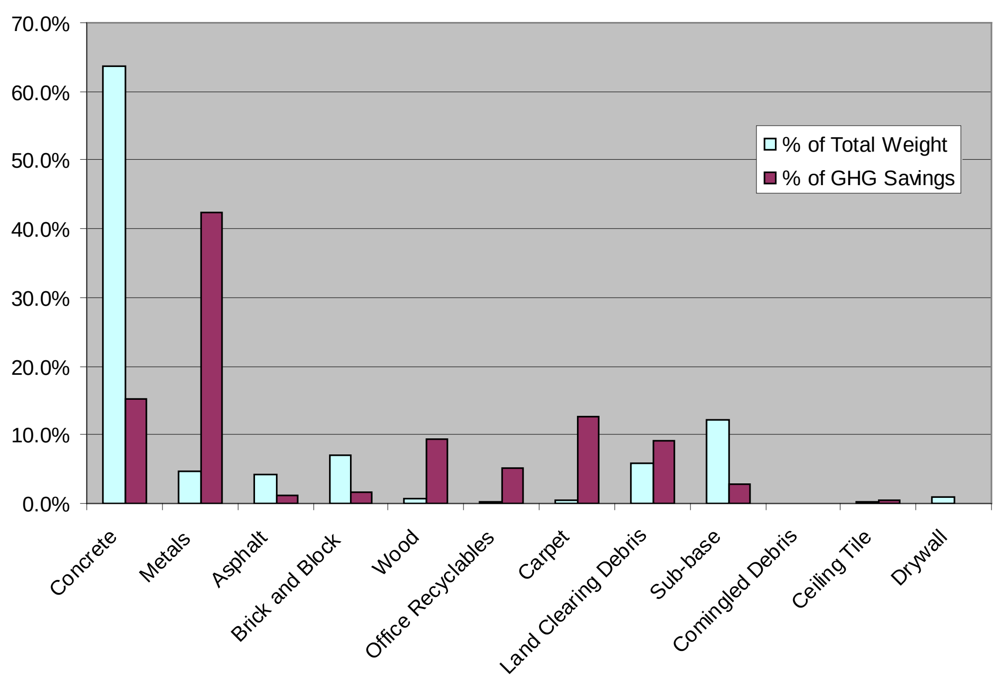

Figure 4-4. Weight compared to greenhouse gas savings

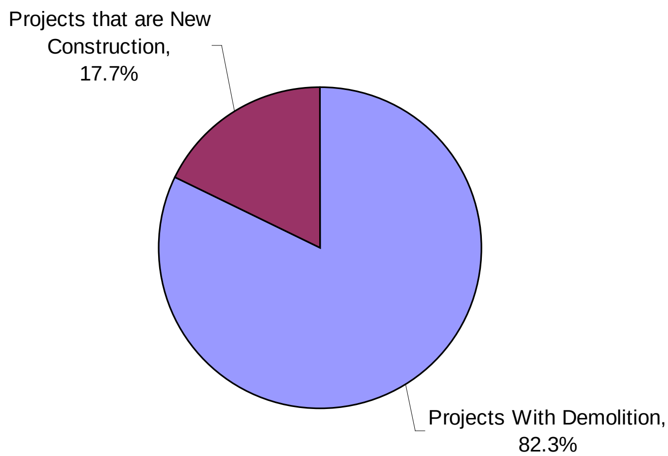

Figure 4-5. Percentages of emissions reductions by type of construction

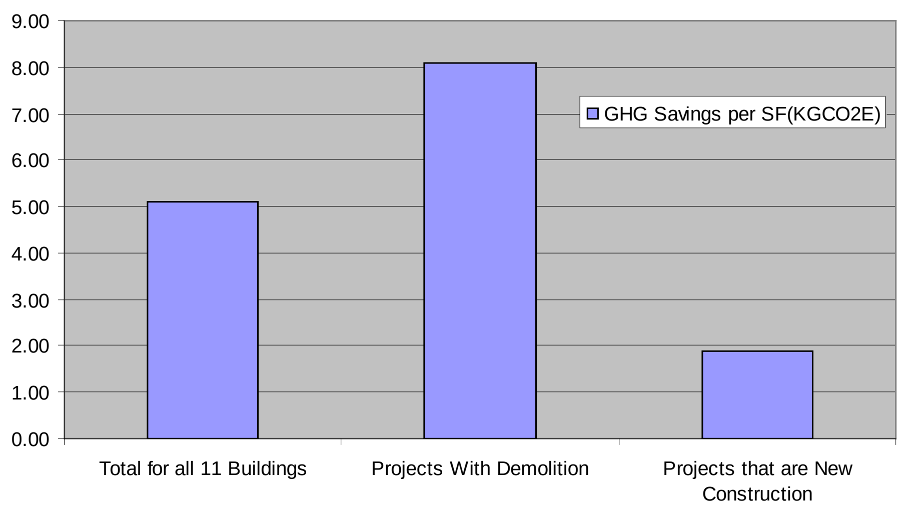

Figure 4-6. Greenhouse gas savings per square foot based on type of construction

CHAPTER 5
ANALYSIS

Materials and projects with highest greenhouse gas emissions reductions: The material with the largest emissions reductions per ton was carpet which was only recycled on the Library West project. However the 64 tons of carpet on that project, 0.4% of total tons of material diverted, accounted for 12.7% of the entire emissions reductions on all 11 projects. Metal, which includes steel, mixed metals, and copper was next. However, steel offered the best opportunity because of its widespread use in building. Metal accounted for 836 tons or 4.6% of the total weight while accounting for 42.3% of the total GHJG emissions reductions. Wood, paper and cardboard also have high emissions reduction factors. However, with many projects already turning to LEED this makes less of an impact because much of this wood, paper and cardboard come from responsibly managed forests. The main reduction from recycling tree based materials is caused because there is no loss in carbon sequestration associated with the harvesting of virgin timber (EPA 2006a). However, in managed forests, carbon sequestration is always on the rise, even during times of harvesting (Alabama Forestry Commission, 2009). With this taken into account the materials that will have the highest emissions reductions impacts during construction and demolition are carpet and steel. Concrete has an impact, but solely because it is used in significant amounts. Carpet offers the highest emission reduction per ton and has a short lifecycle of about 5-15 years depending on the use. Steel offers a high emissions reduction per ton, has many uses and low cost.

From the data set used in this research it is concluded the largest emissions reductions will likely occur on projects that involve demolition, not only new construction, where steel and carpet are recycled.

CHAPTER 6
SUMMARY

Implications for Leadership in Energy and Environmental Design

Material and Resources Credit 2.1 and 2.2 give credits in LEED for achieving a waste diversion rate of 50% and 75% respectively. The diversion rates are based entirely on weight or volume, whichever method the contractor prefers. This method places no emphasis on selecting the best materials to recycle and rather only on reaching a specific goal. After reviewing the GHG emissions data associated with different materials the focus should be placed on selecting the correct materials to recycle rather than on weight or volume alone. Weight and volume do matter but if a project achieves the 75% waste diversion rate by recycling 1500 tons of concrete and landfilling 500 tons of carpet the environmental impact the credit was intended to have is significantly reduced. A weighted scale for all construction materials should be created so that materials with more emissions and recycling impacts have higher values than materials with low emissions and recycling impacts, such as concrete.

Another option to improve LEED would be an Innovation and Design credit for the creation of a building material life cycle analysis and recycling plan. This would allow designers to learn about the overall environmental and cost impacts of selecting materials while creating a plan as well as commitment to recycle appropriate materials at the end of their lifetime. For example the credit could be awarded if a lifecycle analysis of the material was completed and a plan for and commitment to recycle 100% of the material was given.

Estimated Greenhouse Gas Emissions Savings

Currently there are 3,288,432 square feet of LEED certified projects (USGBC 2009b) and another 262,120,695 square feet of LEED registered projects in the state of Florida (Table 6-1). Using the overall average on the 11 UF LEED projects, 5.10 kilograms of emissions avoided per square foot, the LEED projects in Florida produce an estimated GHG emissions savings of 16,771 metric tons of carbon dioxide equivalent. 16,771 metric tons of carbon dioxide is equivalent to 1,903,632 gallons of gasoline consumed or 37,502,000 miles driven (EPA 2009e). Using the average for projects that included no major demolition, only new construction, the estimated total emissions savings in Florida is 6,149 metric tons of carbon dioxide equivalent. At a nationwide level there are 252,260,901 square feet of certified projects and another 3,472,000,498 of registered projects. Using the overall average on the 11 UF LEED projects, 5.10 KG of emissions avoided per square foot, the LEED projects in the U.S. produce an estimated GHG emissions savings of 1,286,531 metric tons of carbon dioxide equivalent. This translates into the emissions savings equivalent to consuming 146,030,760 gallons of gasoline or removing 235,628 passenger vehicles off the road for a year (EPA 2009e). Using the average for projects that included no major demolition, only new construction, 1.87 KG of emissions avoided per square foot, the estimated total emissions savings in the United States is 471,728 metric tons of carbon dioxide equivalent. Assuming that one third of all registered projects in the U.S. reach certification level and that 80.2% (MHC 2006) implement a waste management program that achieves at least Materials and Resources Credit 2.1, the estimated total emissions savings using 1.87 KG of emissions avoided per square foot is 1,733,964 metric tons of carbon dioxide equivalent. The estimated total emissions savings using 5.10 KG of emissions avoided per square foot is 4,728,992 metric tons of carbon dioxide equivalent.

Table 6-1. Leadership in Energy and Environmental Design greenhouse gas emissions savings estimates in Florida and the United States

LEED Projects	Square feet of projects	Number of projects	Emissions avoided at 5.10 KG/SF (MTCO2E)	Emissions avoided at 1.87 KG/SF (MTCO2E)
Florida Certified	3,288,432	41	16,771	6,149
Florida Registered	262,120,695	865	357,018	130,907
U.S. Certified	252,260,901	1,976	1,286,531	471,728
U.S. Registered	3,472,000,498	16,250	4,728,992	1,733,964

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BIOGRAPHICAL SKETCH

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