MATERIAL REUSE IN THE LANDSCAPE: THE FEASIBILITY OF REUSING WOOD IN LANDSCAPE CONSTRUCTION AND DESIGN

by

CHRISTOPHER PAUL MCDOWELL

(Under the Direction of Katherine Melcher)

ABSTRACT

Wood reuse is an effective technique for reducing human impact on the landscape and additionally has much untapped potential in bringing economic, environmental and cultural benefits to the field of landscape construction and design. This thesis examines whether reusing wood is a practical design tool for landscape architects and construction professionals compared to conventional methods. The objective of this study is to gain experiential knowledge through the construction of common landscape items followed by a review of landscape design and construction professionals. The study concludes that reusing building materials scored highly in all categories of design criteria in comparison with the conventional products; however, there are numerous issues that thwart its mainstream use and numerous changes must be made for major reform to take place in the construction industry.

INDEX WORDS: Materials Reuse, Reclaimed Wood, Sustainable Landscape Construction, Deconstruction, Recycling, Industrial Ecology, Construction Ecology, Life Cycle Assessment, Closed Loop Systems, Waste Management, Green Building

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DEDICATION

To my family, friends and everyone who ever supported, encouraged or helped me along the way.

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CHAPTER ONE:

INTRODUCTION

Background

Over the past century, a consumer-driven throwaway culture has emerged, resulting in a glut of single-use, disposable products, which have subsequently led to massive accumulations of *waste*[1] on Earth. "Waste", in modern times, is viewed as a liability to be removed and not a valuable commodity to be reused. As a result, waste has dire implications for climate change and the future of Earth specifically in terms of the management of materials (see Figure 1)[2]. Landscape architects have an increasingly critical role in developing solutions to vastly complicated problems such as waste through the utilization of ecologically responsible design and construction practices. However, in order to make a sizable impact in countering waste, widespread reform within the design and construction industry has to take place, such as a complete reversal of the conventional practices of seeing materials and built products through the lens of a linear or "cradle to grave" single life trajectory and instead through material life cycles.

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[1] In human culture waste is defined as "an unwanted by-product of a manufacturing process or refuse from place of human or animal habitation" (Merriam Webster)

[2] Although globally, the waste management sector only accounts for only 3-5 percent of total anthropogenic greenhouse gas (GHG) emissions, there is tremendous potential for the sector to be a "major saver of emissions" in all other sectors. For example, 42 percent of GHG emissions in the US are a result of the "management of materials" (UNEP, 2010).

The natural environment, for example, is an excellent model for landscape architects in terms of waste efficiency, where very little *waste*[3] is created and waste

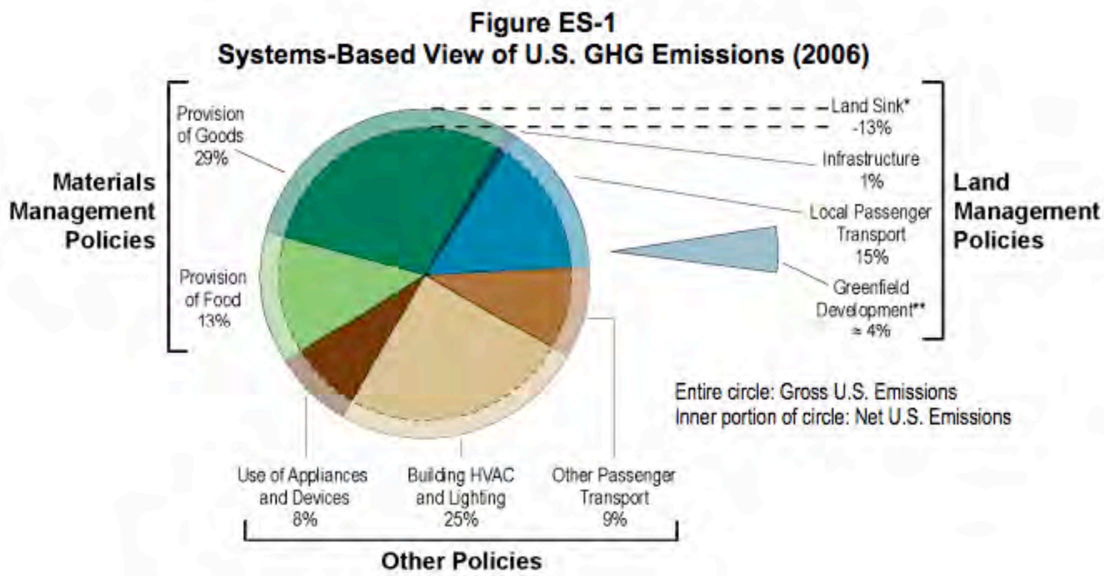

Figure 1: Breakdown of US GHG Emissions by Activity (US EPA, 2009)

materials that are produced, through nutrient cycling or energy flows, are used to the utmost potential during natural processes. A classic example of this is when a tree dies in a forest; it falls to the ground and slowly decays. The decomposition of a dead tree is food for fungi, insects and microorganisms, habitat for animals, and the source of macronutrients and other elements critical in carbon and nutrient cycles that promote the life of other organisms. This process known as *biodegradation*[4] demonstrates why nature is so efficient in dealing with waste and how different humans perceive and handle waste on the linear life cycle trajectory (see Figure 2).

[3] In nature, waste generally does not exist except in instances such as during respiration when 33 percent of heat is considered waste product.
[4] Biodegradation is a term used in both ecology and waste management that refers to the “biological forces that cause decomposition or decay” (Krasny, 2003)

In recent years, however, with the development of the green building industry, designers and construction professionals have become increasingly concerned with

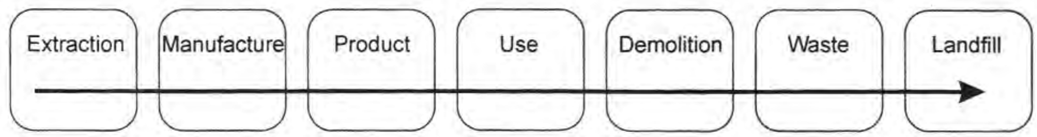

Figure 2: Linear "Cradle to Grave" Life Cycle (Addis 2006)

the origin and fate of building materials as it is now widely known that the production process and landfilling of materials have detrimental consequences to the environment in the form of excessive pollution and degradation to the landscape (EPA 2010; Thompson & Sorvig 2008). Viewing collective human impact in terms of life cycle and development of a *closed loop*[5] system for materials has been the primary focus of the reuse and recycling industry (see Figure 3). Up until this point, conventional practices of design and construction have mostly failed to incorporate *materials reuse*[6], or the reuse of construction materials, into built projects on a large scale despite a growing awareness of the life cycle of materials (Addis 2006). A small yet emerging trend in the field of design is the incorporation of practices such as *deconstruction*[7], *life cycle assessment* (LCA)[8] and materials reuse (MR) into the design

[5] Closed loop is a term coined in the field of Industrial Ecology (IE) that refers to a system of material flows that actively reuse waste as opposed to an open loop system where a product is ultimately a waste product (Kibert, Sendzimir & Guy 2001).
[6] Materials reuse is industry jargon used to describe the reuse of construction materials in the field of building deconstruction.
[7] Deconstruction is the process of systematically dismantling building components with the intention of reuse or recycling.
[8] Life cycle assessment is the technique of assessing a products environmental impact from production to end life or "cradle to grave" (Thompson & Sorvig 2008).

process. In addition, contemporary design industry standards such as Leadership in Energy Efficient Design (LEED) and the Sustainable Sites Initiative (SITES) similarly

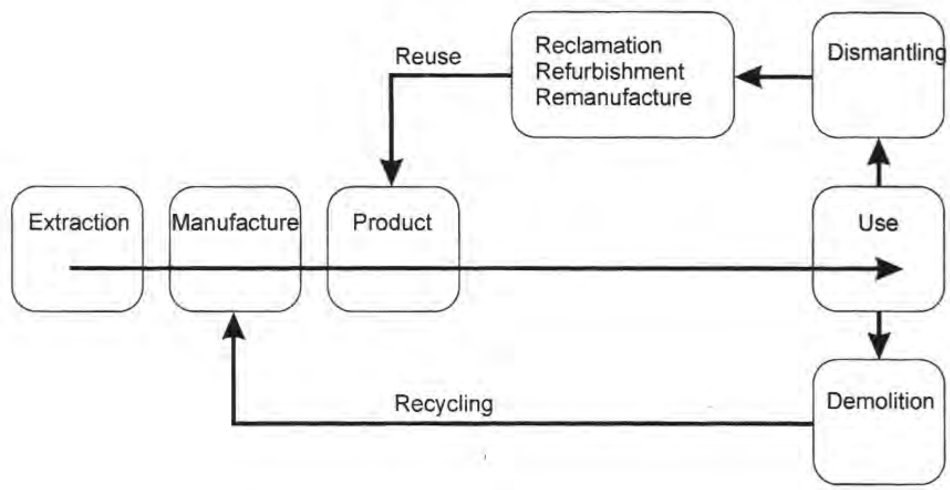

Figure 3: Closed Loop Life Cycle (Addis 2006)

promote and incentivize the reuse of materials in design and construction projects through certification credits. Even with a burgeoning green building industry, deconstruction and materials reuse remains relatively obscure and underutilized by design professionals. Additionally, the US design and construction industry, still recovering from a gigantic housing crisis and economic recession is mostly ambivalent to materials reuse and green building as a result of issues ranging from lack of commitment by stakeholders to worry over increased costs associated with reuse and green building activities (Zou and Couani 2012). This perceived fear of reusing waste is particularly evident in the fact that construction and demolition (C&D) waste accounts for a majority of industrial waste equivalent to 136 million metric tons (MMT) or 500 kg (1100 lbs.) per capita (Kibert, Sendzimir and Guy 2001). Although recycling and reuse has improved substantially since 1990, only ten to twenty percent of this total is diverted annually, mainly in the form of metal and concrete recycling, which commands a high market value (Kibert, Sendzimir and Guy 2001). Nonetheless, materials reuse - or in the case of this study, wood reuse - presents an abundantly beneficial opportunity for landscape architects to design and construct meaningful, aesthetically pleasing landscapes while adhering to environmental values of the green building movement such as the reduction of C&D waste.

Thesis: Reusing Wood in the Landscape

Although there are numerous types of materials that landscape architects and contractors will ultimately specify in design projects, wood is one such product that is universally used, has historically been used since the recording of modern time and also is a building material that is truly considered to be sustainable as it contains the lowest *embodied energy*[9]. Wood is an immensely popular and trusted brand in the design and construction world because it is generally easy to use, is cost efficient and a plentiful renewable resource in the United States, that is, if it is harvested sustainably. Wood waste, or reclaimed wood, which is virtually an untapped resource, shares all the attributes of wood and much more. Reclaimed wood, that is wood harvested or salvaged from building demolition, renovation or construction projects tends to be older-growth, denser and generally higher quality wood with the added benefit of reducing the environmental toll of waste such as the increase of greenhouse gases due to landfilling and the depletion of natural resources (Thompson and Sorvig 2008).

[9] Embodied energy is referred to as the total energy used to create a product.

The specific emphasis of this thesis is to look at the effectiveness of wood waste reuse or reclaimed wood as a sustainable building material and design tool for landscape architects compared to *conventional*[10] lumber. The reuse of wood in the landscape has the potential to not only provide economic and ecological values to design and construction projects but also has the power to inform the design process and connect the site with a tangible historical and cultural meaning or sense of place (Calkins 2002). Thus this study is designed to compare both the use of reused and conventional lumber in landscape design and construction in order to answer the following research question and sub questions: *what is the feasibility of reusing wood in landscape construction and design? How does it compare to conventional lumber products? What are the impediments to wood reuse as an effective design tool? What is the future outlook and opportunities for reclaimed lumber in the field of landscape architecture?*

In this study, the primary method for investigating waste reuse is to develop and physically construct reuse prototypes of three common landscape structures – a tool shed, fence with gate, and raised bed - that can be evaluated and marketed alongside comparison structures constructed with conventional lumber for the purposes of demonstrating the feasibility of reclaimed wood as a valuable construction material. In order to truly explore the diversity and breadth of wood waste as a building material, each landscape structure will be made from three different types of the following common wood wastes: wood scraps less than four feet, full-length dimensional barn lumber and wooden pallets. Dubbed the "Reuse

[10] Conventional lumber is deemed as virgin lumber products sold commercially in the US.

Village," the physical construction project will be located publicly[11] on the UGA campus in Athens, Georgia.

After construction is complete, a formal review of each of the reuse products in comparison to its conventional counterpart is administered using an outside panel of design and construction professionals. Each participant is selected to individually grade the landscape structures according to five criteria that are integral to product design: aesthetics, affordability, durability, efficiency and ecological impact. Study participants will assess each structure using their own professional opinions in addition to supplemental qualitative and quantitative data provided from the research and construction process. Further explanation of this process will be discussed in the methodology (Chapter 2) and implementation (Chapter 3) chapters.

The overall concept of this study in "testing the built product" is to gain practical insight into all phases of the reuse process from material procurement to pre-planning and design to construction implementation. Documenting this process in addition to researching the current body of literature will ideally create a more thoughtful way of investigating this subject. Prior to the development and construction of reuse prototypes, this study will investigate the existing literature on the topic of materials and wood reuse in landscape construction and design which includes subjects such as the history and significance of wood and wood reuse, the origins of construction ecology and life cycle analysis, material culture, nature and waste, reuse as design tool, the value of wood in the landscape, wood waste as a

[11] The "Reuse Village" is specifically located at the UGArden, an interdisciplinary student-managed agricultural facility on UGA's South Campus and salvaged materials are provided by the Material Reuse Program, a student-run deconstruction and reuse program.

resource, the value of reuse wood in the landscape and quantifying reuse. A conclusion will be drawn according to the analysis of existing research on the subject, experiential knowledge gained from the process of physical construction and study findings as a result of the survey of professional opinions.

Structure

Chapter 2 of this study focuses on the literature review of books, articles, journals and other publications pertaining to subjects in and around reusing wood in landscape architecture in addition to an examination of the traditional timber market and importance of wood as a building material. Other subjects browsed are topics regarding the connection of nature and industrial processes, which form the theoretical framework and foundation for reuse and green building. Although there are many books on waste reuse and recycling in general, construction materials reuse and wood reuse are relatively obscure topics in terms of academic publications. However, as a result of the growing green building industry publications on wood reuse and related subjects has been steadily increasing.

Chapter 3 is dedicated to the study methodology and composition of the study design, which is the heart of this research project. Chapter 4 explains the implementation and experiential process of the built project that examines more closely how the built project was physically constructed according to each zone or waste product. Chapter 5 is an analysis of the study findings and finally Chapter 6 is the conclusion of the research thesis including the implications of reuse as a viable industry in landscape architecture, its impediments and future outlook.

Delimitations

This thesis is primarily focused on the application of reuse of wood in landscape design and construction within the United States, despite its possible widespread utilization in other countries. Facts and figures are based on the industry of timber, reuse and waste management in the United States. In addition, this study is focused solely on reusing wood and not other salvaged materials, though there are many comparisons that can be drawn across the spectrum. Salvaged wood and wood in general are discussed here in order to compare and contrast the two materials as green building products. Looking at salvaged lumber reuse in the landscape can also be beneficial in analyzing challenges and opportunities within the larger framework of the green building industry as they are interrelated; however, this study is primarily focused on looking at the issues from a relatively small scale through the lens of a modest building project.

CHAPTER TWO:

LITERATURE REVIEW

History and Significance of Timber, Demolition and Reuse in the US

Timber and Wood Based Products

One of the largest and most reliable commodities in the United States market is found in its timber reserve. The reason for this is that America has an immense resource in its forests. More than one-third of this nation's land mass is covered in forest (Falk 2004). Prior to European settlement that number was closer to one-half of US land mass (Falk 2004). In the 300 or so years between colonization and the present, a lot has changed, particularly in the distribution, composition and quality of timber in forests.

Massive deforestation beginning in the mid-1800s decimated vast stands of old-growth trees from the Blue Ridge to the California Coast. However, the assault of pristine virgin forests really began in earnest as the country swelled in population as a result of the Industrial Revolution. Fueled by massive immigration into the 'Land of Opportunity' and expansion of a westward railroad network, population in the US almost doubled from 50 million to 96 million people between 1880 and 1910 (Earley 2004). As immigrants moved westward and cities exploded across the country, the demand for lumber used in the construction of houses and factories increased exponentially.

In terms of forest exploitation, the Longleaf pine is a somber reminder of the extent of environmental damage done during the turn-of-the-century industrial expansion. The Longleaf pine ecosystem once comprised one of "the most extensive ecosystems in North America," stretching along the coastal plain of the Gulf Coast from Texas to Virginia, and prior to European development spanned nearly 92 million acres (Earley 2004, 1). The insatiable appetite for timber products coupled with steam-powered mechanization of saw mills and railroad expansion (see Figure 4) allowed loggers to clear cut at feverish clip and "by 1892, the annual Longleaf cut alone was estimated at 7 billion board feet" (Earley 2004,161). Today, the Longleaf accounts for a paltry 2.95 million acres – a 97 percent decline - scattered across 150,000 square miles of the more generic forests and pine plantations of the Southeast, where *Southern Yellow pine* [12] is the dominant variety.

The rise and fall of the Longleaf forest is also telling of the composition of forests in the US. Despite years of forest degradation, much of the tree cover has been restored; however, the character of US forests has significantly changed (Falk 2004). It is well known that the quality of timber has precipitously declined in the past century due to the excessive rate of timber felling compared to the meticulous rate at which forests naturally mature. The old, slow-growth forests of the US are no longer available, nor will they ever be. The emergence of sustainable forestry practices along with conservation measures will ultimately lead to a better stock of timber, but could take decades if not centuries to notice dramatic improvements.

[12] Southern Yellow Pine (SYP) refers to a larger category of tree in the Southeast, of which Slash Pine, Short-Leaf Pine, Longleaf Pine and Loblolly Pine species are dominant.

Regardless of quality, the US economy still depends greatly on its massive forest reserve. A report created by the USDA Forest Products Laboratory (FPL) in

Figure 4: Cutting the Longleaf Pine circa 1900 (source: US Fish & Wildlife Service)

Madison, Wisconsin describes in detail US timber production numbers of 2002 (Falk 2004). In 2002, 520 million cubic meters of *industrial roundwood*[13] was consumed in the US, of which 70 percent (384 million cubic meters) was used in solid wood products and 30 percent used in pulpwood products. Large amounts of residue created during the production of solid wood products in addition to pulpwood are used to create paper. Of the 520 million cubic meters of industrial roundwood consumed, (dimensional) lumber accounts for a majority (78 percent) used in the fabrication of construction materials whereas the remainder (22 percent) is found in paneling such as plywood. In terms of softwood production, from mainly Douglas-fir and Southern pine trees, the US consumed 109 million cubic meters (57 million metric tons) half of which was produced domestically and half imported from Canada. The bulk of softwood products were used in new residential construction and renovations. Hardwood products, which account for a much smaller 27 million cubic meters (19 million metric tons) of consumption, were mainly used in the production of packaging and shipping products such as wooden pallets (Falk 2004).

Understanding the impact that timber production has on the landscape is important for everyone involved in environmental design and construction. Logging, for example, elevates erosion on average by 500 times and reduction of tree canopy and forest cover greatly decreases "global ability to process CO_2" critical to the factors of climate change (Thompson and Sorvig 2008). Timber production, if carried out haphazardly, is directly responsible for numerous other deleterious results such as

[13] Industrial roundwood is a forestry term referring to lumber used in industrial production of lumber, plywood and pulpwood products.

emissions during production and transport, habitat decline and depletion of natural resources. Knowing the environmental costs associated with varying methods of lumber production (clear cutting versus sustainable forestry) is critical in creating ecologically thoughtful design and providing a strong footing for green building.

Demolition

In his conclusion to *Preserving the World's Great Cities*, Anthony Tung remarked that during the twentieth century, "not only has modern civilization destroyed much of the architectural fabric inherited from previous generations, creating a wide chasm between us and our past, but, worse, on every continent we have adopted a culture of destruction that presages further loss" (Tung 2001, 1). Presently in the US, *demolition*[14] is a multi-billion dollar industry, but this took some time. The process of demolition, which particularly rose to prominence after major disaster events such as the great fire of New York in 1835 and the monumental Chicago fire of 1871 was dramatically improved in 1867 as renowned scientist Alfred Nobel patented dynamite (Byles 2005). Not coincidentally, destruction and demolition of cities in the US, similar to the considerable demand for timber products at the turn-of-the-century, grew tremendously as a result of staggering population growth and massive industrial expansion. Billed as progress and later urban renewal[15], the modernization of America required the clearing of large tracts of land of the old cities in an effort to increase

[14] Demolition is the process of tearing down or razing a building or structure (Merriam-Webster).
[15] Urban renewal is a building practice involving large-scale demolition of urban fabric for the purposes of economic redevelopment. Although the concept of urban renewal was made popular by planning luminaries such as Baron Haussmann and Robert Moses, it gained steam in the 1960s and 1970s as a tool of "community development" under the Johnson administration and was particularly criticized by Jane Jacobs in *The Death and Life of Great American Cities*.

mobility, raise public health standards and improve social and economic conditions (Tung 2001).

Throughout US history, demolition by explosives, from high-rise towers to casinos, has captured the attention of many Americans and virtually functioned as a spectator sport, such as the festivities surrounding the implosion of the King Dome in 2000 (Byles 2005). In contrast, demolition has also served as a cathartic cleansing for a grieving nation in the wake of terror attacks on the Edward Murrah building in 1995 and Twin Towers in 2001. Whether a block of shotgun houses in New Orleans is bulldozed to make way for green space or a complex of urban renewal era housing projects in Chicago are razed for new development, the process of demolition is an integral component to the construction of the built environment.

Considering that demolition is a necessary function for growth, management of its resulting waste is similarly important. In 2003, demolition of residential and non-residential structures accounted for 50 percent of the 170 million metric tons of C&D waste created in the US (EPA 2003). In that same total renovation accounted for 41 percent and new construction made up only 9 percent of the total of C&D waste generation (see Figure 5). In waste wood alone, the US generated 62.5 million[16] metric tons in 2002, almost half of which (27.1 million metric tons[17]) was deemed "recoverable waste wood" (Falk 2004).

[16] This number is reflective of C&D materials in the municipal solid waste (MSW) stream.
[17] Roughly 32 percent of recoverable waste wood was MSW, 29 percent was construction waste and 39 percent was demolition waste (Falk 2004).

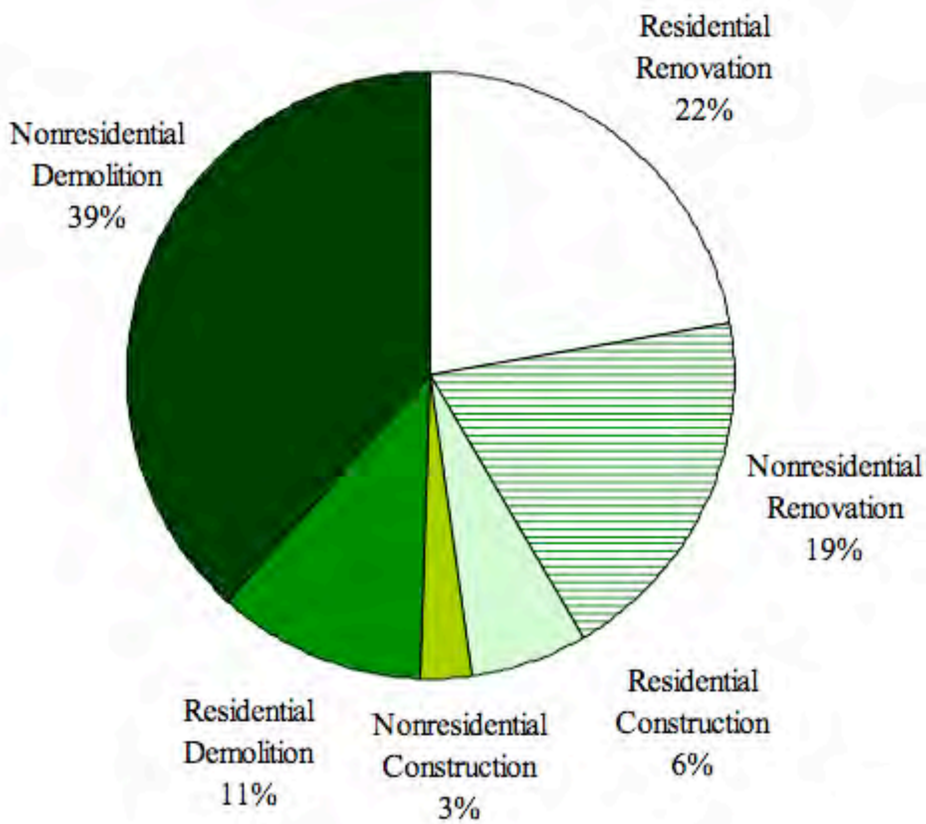

Figure 5: Percentage of Residential and Non Residential Waste by Category (source: EPA 2003)

Reuse

Reusing building components has similarly been carried out for many centuries. In fact, the Romans pillaged their own ancient sites of marble and stone in order to build modern Renaissance structures in Italy (Tung 2001). It was discovered in the fifteenth century that pulverizing marble created a superior plaster with a luminous finish and as a new Rome emerged to be a religious center for the world, buildings of the long diminished Imperial Rome were dismembered and quarried methodically to support massive building projects (Tung 2001).

In modern day, reuse and recycling are particularly relevant to low-income and rural communities, especially for developing countries. In the developing world, reuse is a tool for survival, and moreover, generating waste is too costly (UNEP 2010). There also is established positive correlation in waste generation rates to per capita energy consumption and GDP as well as amount of available land (UNEP 2010; Crawford 2011). In this respect, countries like the US and Australia with higher GDP and large expanses of undeveloped land have far greater landfilling rates (see Figure 6).

From tires to pacemakers, developing countries reuse the developed world's waste, and, as a result, jobs are created in the process. The ship-breaking and recycling industry (SBRI) in Bangladesh, for example, where workers dismantle and recycle metal ships at end-life, though particularly dangerous and detrimental to the environment, accounts for nearly 200,000 of the country's workforce along the supply chain (WB 2010). In addition, SBRI accounted for 50 percent of the steel production in Bangladesh as 70 percent of all ships are recycled in the countries of Bangladesh, Pakistan and India (WB 2010). Interestingly, in the case of SBRI in Bangladesh, global shipping markets are the central determinant in the supply and demand of ships to be recycled, for instance if freight rates are up then ship breaking declines. The demand side of scrap metal is a direct function of the price of steel (WB 2010). The SBRI industry is a valuable global model in comparing to the salvaged and recycled materials market in America, which also present similar environmental and economic costs and benefits to society.

The reuse and recycling market in the US is generally subdivided by waste type. In the case of this study, the focus is primarily on C&D waste. Although, depending on the state, C&D waste can be included in MSW totals. In the US, reuse and recycling of the C&D waste stream is heavily dominated by metal and aggregate recycling because of its significant financial return (Kibert, Sendzimir and Guy 2001). In 2004, as a result of a building boom in China, scrap metal prices soared to more than $300 per ton up from $77 a few years prior (Byles 2005). Although the proportion of C&D waste reused or recycled is not currently known, the rates are likely small, at 10 to 20 percent of total C&D waste produced (Kibert, Sendzimir and Guy 2001). Aside from scrap metal and aggregate recycling, most C&D waste is landfilled or incinerated (EPA 2010).

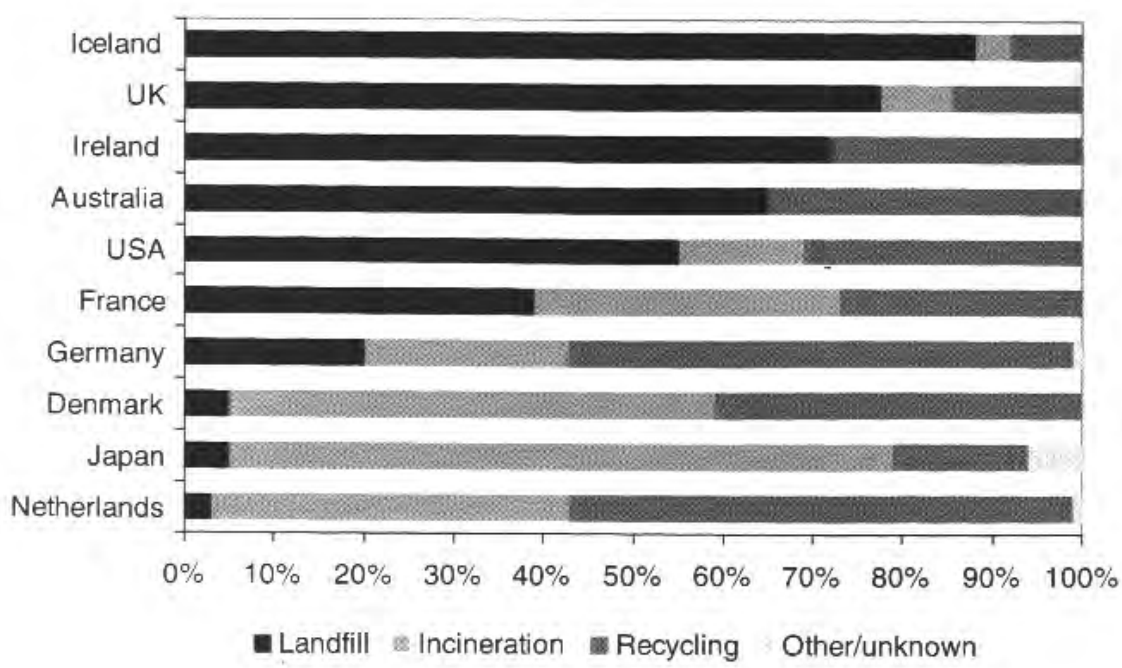

Figure 6: Treatment of Municipal Waste by Selected Developed Countries, 2003 (source: Crawford 2011)

Although it has been around since the days of Ancient Egypt, reuse and recycling has only reemerged as a common practice in the past thirty years. Beginning in the 1960's and 1970's popular opinion regarding the environment and waste changed precipitously as a result of growing social anxiety over humans impact on nature as evidenced in landmark texts such as Rachel Carson's *Silent Spring* (1962) and Paul Ehrlich's *The Population Bomb* (1968). By the early 1990's consumer waste recycling had become standard, whereas a decade before it was relatively unknown to the public aside from contractors and metal scrappers.

A fundamental aspect of contemporary waste management, memorable in the slogan "reduce, reuse, recycle" is the waste hierarchy (see Figure 7), where reduction is highest priority followed by reuse, then recycling and waste to energy (Addis 2006). Disposal of waste is, of course, considered the least desirable. The closed loop life cycle of building materials modeled after natural systems represents the "ideal approach" as shown in Figure 3 is the basis for the recycling and reuse industry (Addis 2006, 12). For reuse to gain prominence over recycling, how we design and construct buildings become increasingly important in the future (Addis 2006).

Emerging reuse industries within the closed loop approach such as deconstruction and materials reuse are quite possibly a more aggressive 21st century incarnation of consumer waste recycling. Reuse, in general, can refer to the *adaptive reuse*[18] or renovation of entire structures or can involve reclaiming individual building products or materials, also known as materials reuse (defined in Chapter 1). Deconstruction and salvage are the primary means for extracting materials for reuse. For the most part, materials reuse has existed as a fringe activity in a small niche within the bulky demolition industry, but it has nonetheless risen to prominence with the popularity of green building. Materials reuse, often mistaken for materials recycling, is

[18] Adaptive reuse is the repurposing of buildings with a different use that they were intended for.

a practice that strategically seeks to reuse construction waste from deconstructed buildings in the construction of new buildings where building materials still function in their original form but with a new life. Recycling, on the other hand, involves processing and re-application as a new product; for example, taking aluminum cans to a scrap yard where they are processed and re-manufactured into another aluminum product.

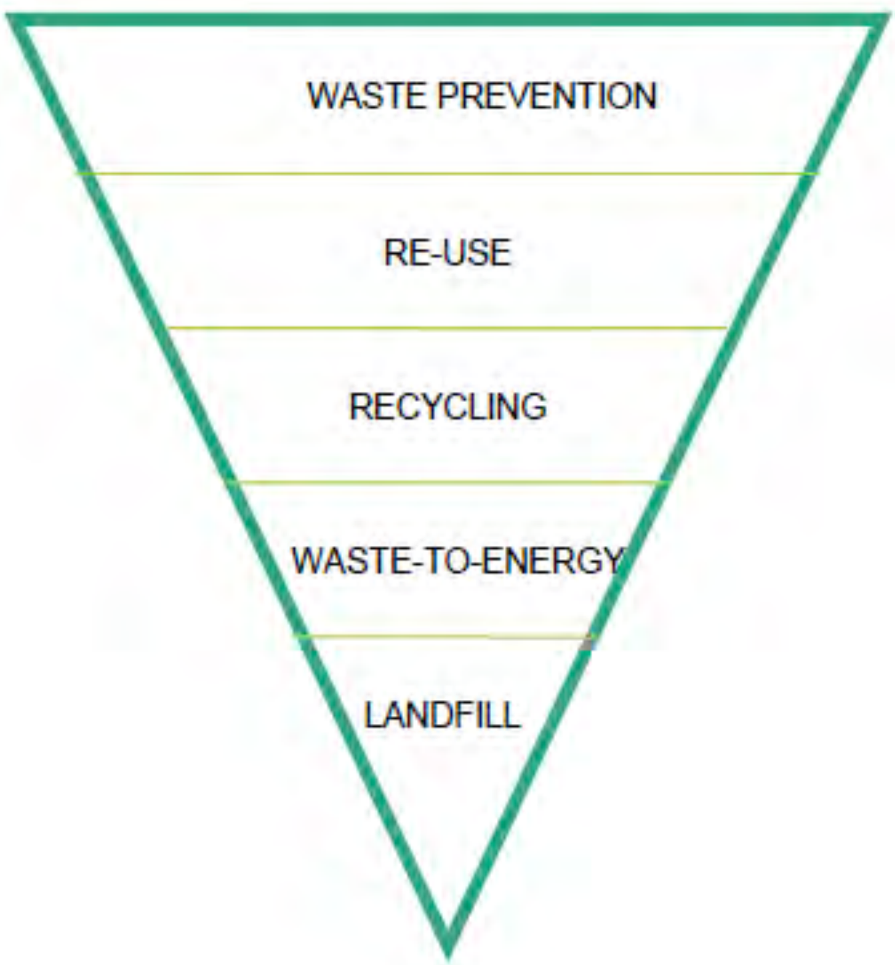

Figure 7: The Waste Hierarchy (source: UNEP 2010)

Materials reuse and its deconstruction counterpart, though a small field compared to recycling, has been championed as a better approach than recycling in numerous areas because it promotes the reclamation and reuse of virgin materials, reduction in landfill waste, sustainable removal of obsolete buildings and subsequent economic activity as a result of salvage (Guy 2002). Recovery rates in deconstruction can be quite high if coupled with recycling, ranging from 50 to 90 percent (Guy and Falk 2005). In comparison to wood recovery in deconstruction[19], the much larger and established recycling industry recovered 65.5 percent of paper and paperboard products and 63.1 percent of steel from the MSW waste stream (EPA 2008).

In terms of commercial market value, the building materials reuse and recycling industry is still evolving. Today, it is not uncommon to find architectural salvage stores and recycling yards in most medium or large cities nationwide. There are generally two types of salvage stores in the US: the community-based non-profit and high-end for-profit. Although, the types of salvage stores can deviate from these two models, the community-based non-profit salvage store (such as Habitat ReStore) features building materials, furniture and appliances similar to the common thrift store in contrast to the high-end for-profit store that either focuses on a specific high-dollar item like reclaimed flooring or operates like an antique store. A third and less visible market is a deconstruction and salvage contractor that sells reclaimed materials according to wholesale prices. In 2003, a telephone survey conducted revealed that there were more than 1,000 companies solely involved in wood-framed building

[19] Quantities of deconstructed wood recovered according to MSW and C&D totals are unknown at this time; however, wood recovered through recycling and total recoverable wood is available (Falk, 2002).

deconstruction and reuse (see Table 1), and within that total more than 500 retail operations (Guy and Falk 2005). Due to the small size of this niche market, information on sales and market share is not publicly available. Regardless, the importance of this information lies in the fact that where stores and salvage operations are present, a market for builders, contractors and clients of salvaged materials slowly emerges. The availability of materials is dependent on the salvage network and if it exists.

Table 1: US Companies in Wood-framed Building Deconstruction and Reuse, 2003 (source: Guy and Falk 2005)

Companies surveyed	Category code	Number
Total		1,078
Broker of recovered materials only	BR	15
Building contractor or trade that uses reclaimed lumber in projects only	CN	6
Deconstruction company that practices partial or whole building disassembly for the purposes of recovering building materials for reuse or a deconstruction company that also does any other activity listed above	DC	219
Demolition company that engages in selective dismantling and deconstruction that also does any other activity listed above	DM	166
Producer or dealer of equipment used in building deconstruction	EQ	3
Environmental services company, such as asbestos or lead abatement	EV	
Materials recycler only	RC	21
Used building materials retail sales, plus those that do BR, CN, or VA	UMS	534
Producer/seller of value-added products, plus those that do BR, CN, or RC	VA	114

Industrial Ecology (IE) and the Biological Component of Waste

Going back to the model of biodegradation, nature and ecosystems are important sources for information in the search for a more sustainable way of life. When a tree dies in a forest, it is not merely a dead tree to be hauled off as waste, but a beacon of life for thousands of soil microbes and other microorganisms that break down decaying material. The nutrient recycling phenomena of the Earth's biological communities is not only fascinating but significant because, as William McDonough and Michael Braumgart describe, Earth is mostly a "closed system" where its "basic elements are valuable and finite" (McDonough and Braumgart 2004, 103). Essentially there are no waste byproducts in nature, aside from heat loss, and it seems that every organism has a purpose in the complex world of life and death.

An emerging field, Industrial Ecology (IE) is the study of material and energy flows through industrial systems, uses the biological world not only as a metaphor for understanding material flows but also as a framework for reversing the industrial processes that have followed the linear (open loop) flow of building materials. The highly efficient and eternally sustainable ecosystem model serves as the basis for the design of industrial systems that Industrial Ecology seeks to attain (Kibert, Sendzimir and Guy 2001). Concepts in IE such as "eco-efficiency" essentially call for the reduction of material and energy outputs, the increased recyclability and durability of materials and maximizing resources as much as possible.

The way in which people design products is particularly insightful to how they view their roles on Earth. Is your newspaper recycled post-consumer product? Are you eating barbeque from a non-biodegradable Styrofoam plate? In modern times we are much more likely to see products that have some recycled or reused content but unfortunately our entire way of thinking is not geared to automatically reuse items nor are our products designed to have a lengthy life cycle. In *Cradle to Cradle*, the landmark text on waste and industrial product design, the William McDonough and Michael Braumgart urge the reader to not only think about the ramifications of the current system but also that a “new revolution” must take place to alter the way we interact with Earth (McDonough and Braumgart 2004).

Life cycle assessment (LCA) is another important concept that was spawned as a result of the growing body of knowledge on industrial ecology. LCA is a technique developed to assess environmental impacts in regards to each stage in a products life. For example, when a building is constructed, it will typically last from a single decade to possibly a hundred years or more; moreover, during this time it has a “life cycle.” The stages of the life cycle in a building would begin with raw material extraction, manufacturing and construction. After it is built, the building is operated and maintained, demolished and disposed of (see Figure 8). During this process natural resources including water and power are consumed and emissions and pollution are released (see Figure 9). The integration of life cycle assessment of building materials can potentially assist in providing the construction industry with much-needed tools in assessing the environmental impact of building materials and the built environment. One criticism of LCA is that “many approaches are manufacturer-specific and suffer from limited data” (Thompson and Sorvig 2008, 250).

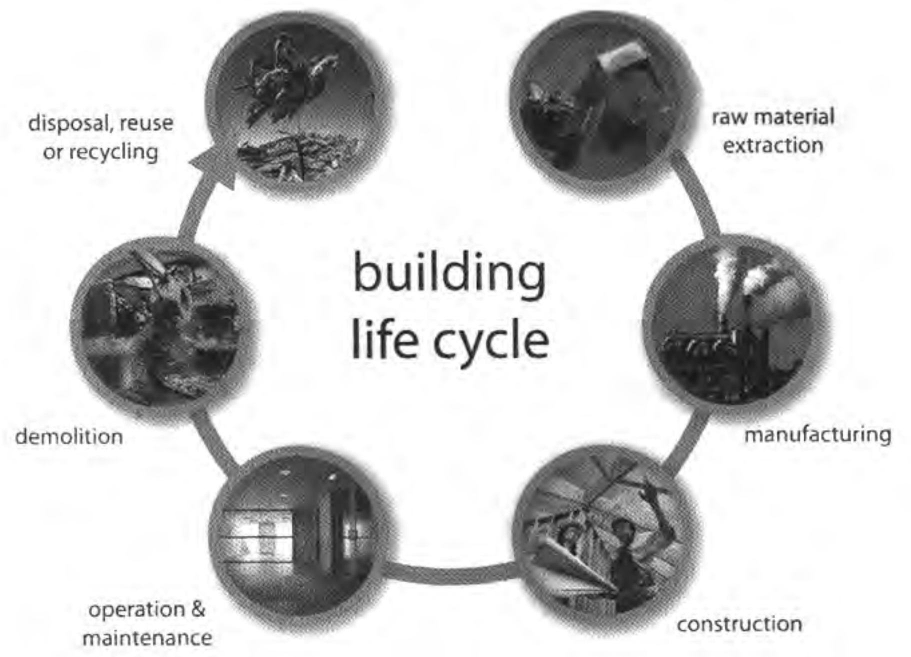

Figure 8: Building Life Cycle Stages (source: Crawford 2011)

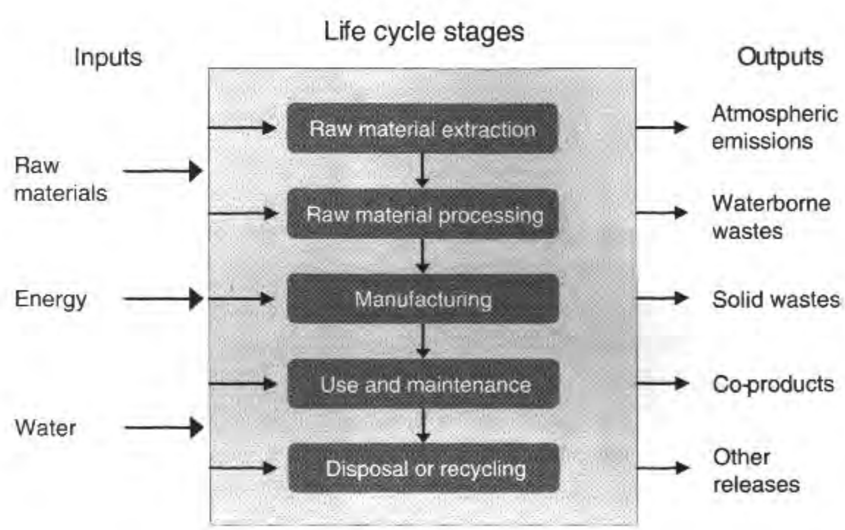

Figure 9: Inputs and Outputs of Building Life Cycle (source: Crawford 2011)

Construction Ecology

Similar to the issues raised in industrial ecology, construction ecology is an attempt to study the impact that man-made activities (such as construction) have on the environment in terms of material and energy flows. Construction ecology "articulates the philosophical and technological foundations" for the global green building movement (Kibert, Sendzimir and Guy 2001, 23). Although the built environment is made from industrial products such as lumber construction ecology and industrial ecology are different. Charles Kibert, a leader in the green building movement and author of *Construction Ecology* argues that the built environment is "not merely an industrial product" but rather buildings are "perhaps the most significant artifacts of human culture and share historic meaning" across a large span of time (Kibert Sendzimir and Guy 2001, 1). In correspondence with life cycle, buildings consume significant resources and create great amounts of pollution and waste from extraction to operation and ultimately end-life.

The construction industry differs from the industrial sector in that the built environment is not subject to the same quality control checks as industrial products and buildings have a widely varying and unpredictable service life. The built environment also takes up considerable amounts of land that greatly affects the natural environment. In the same way that reuse struggles to inject itself into the construction and demolition market, the principles of construction ecology go against the established framework of the construction industry, an open loop system characterized by massive pollution, energy waste and ecological disruption. Instead the construction ecology and green building movement seek to reform and integrate construction with nature through closed loop strategies that focus on utilizing renewable, biodegradable, recyclable or reusable materials (Kibert, Sendzimir and Guy 2001).

Value of Reuse as a Design and Construction Tool

The culmination of the aforementioned topics on the production and use of construction materials sets up a framework for why reuse is particularly important in environmental design as well as landscape architecture. Construction materials, at the current pace of building, are highly inefficient and costly to Earth if they are used irresponsibly. From construction ecology to materials reuse, the underlying theme in modern green building theory is that closing the loop of building materials through a combination of strategies such as reuse, recycling and energy efficient design can greatly improve conditions or at least minimize humans impact on Earth.

That being said, reuse is time-consuming and laborious. It requires a designer and contractor (see Figure 10) to provide for extra lead time in selecting and procuring materials, navigating regulations, and coordinating with subcontractors and other parties as well as potentially presenting hidden costs and safety challenges (Addis 2006). The end reward, however, can be substantial in terms of energy savings, reducing environmental costs, improving cultural and aesthetic value to projects and providing economic incentives.

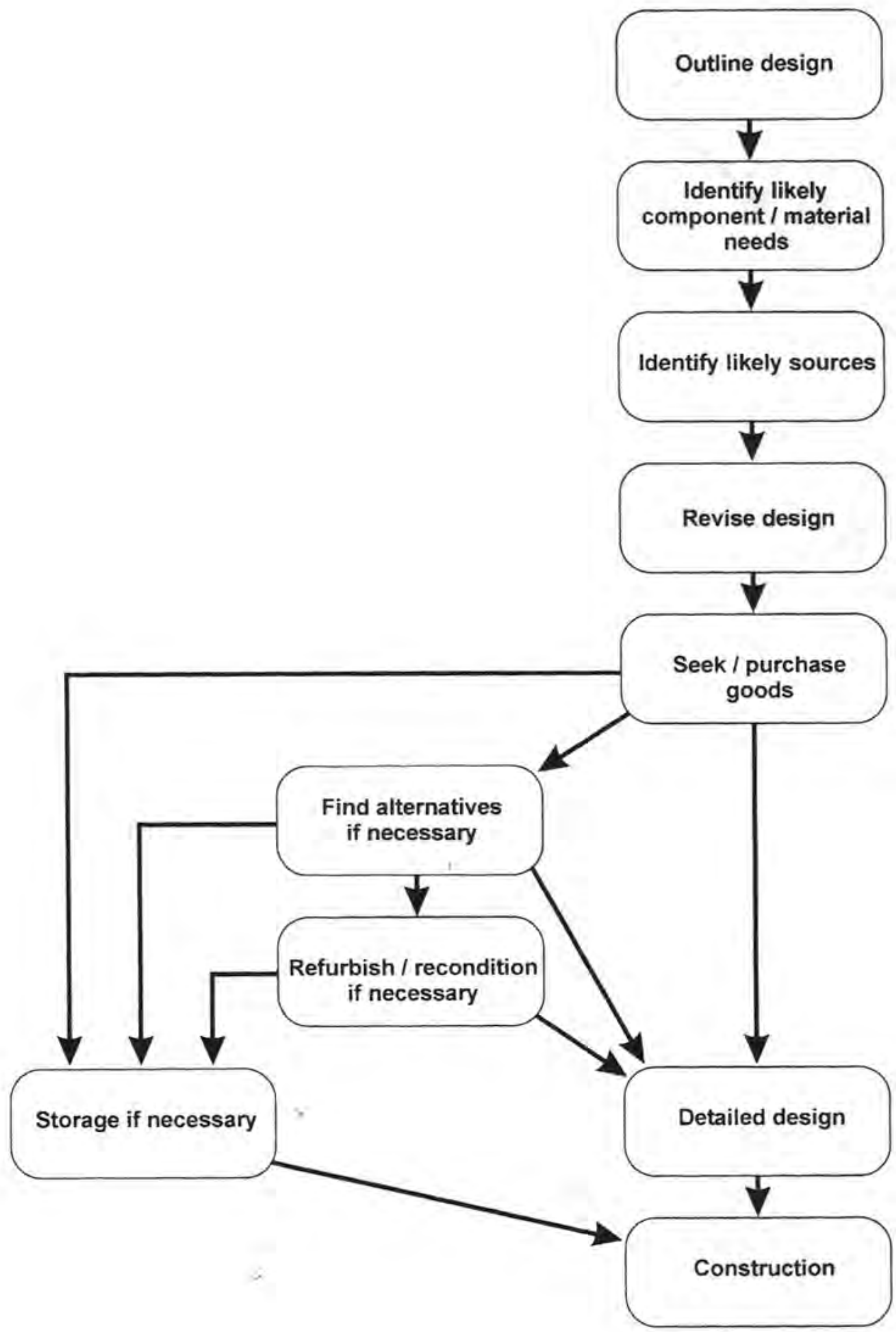

Figure 10: Designer and Client Perspective of Reuse (source: Addis 2006)

Value of Wood as a Sustainable Building Material

Although timber harvesting and production can have extreme impacts on the landscape, wood is considered an extremely valuable material in the green building industry. The *built environment*[20] has a tremendous impact on the natural environment, which why it is a chief concern of the green building movement. While only representing 8 percent of GDP, the construction sector consumes a disproportionate amount of resources in the US. It "consumes 40 percent of all extracted materials, produces one-third of total landfill waste and accounts for 30 percent of national energy consumption in its operation" (Kibert, Sendzimir and Guy 2001, 7). Wood is significant in this respect because of its widespread use and its standing as a reliable construction material, but more importantly because of the plethora of positive attributes that wood exhibits in relation to the environment. Considering that almost half of timber harvested in the forest ends up as a construction building material, wood has extensive implications in the built environment (Falk 2010).

Wood has a low embodied energy. From production and transportation to the marketplace very little energy is used in its production. Wood is also unique from other materials in that it is renewable, it has low carbon implications and it is not extracted from the Earth like metals, rock or concrete, which use massive amounts of energy and water (Falk, 2010). Energy from the sun is responsible for the growth (production) of a tree, whereas fossil fuels are responsible for the industrial fabrication

[20] The built environment generally refers to all human designed, constructed and managed settlements, structures and infrastructure.

of construction materials such as metal and concrete. Another mostly unknown fact is that the timber industry primarily uses carbon-neutral *biomass*[21] as its main energy source (see Table 2), to which it creates on its own during the wood production process (EPA, 2007). Kiln-dried wood, for example, is one of the more energy costly production processes in the manufacture of wood; however, bioenergy from the lumber mill's wood chips, is often used to heat the kiln.

Table 2: Fuel Sources for Timber Industry (Falk 2010)

Fuel source	Proportion used (%)
Net electricity	19
Natural gas	16
Fuel oil	3
Other (primarily biomass)	61

[a]EPA (2007).

Forests also have tremendous implications on the carbon cycle. Photosynthesis is an important process that helps to remove carbon from the atmosphere and subsequently trees and other vegetation play an enormous role in this process. Deforestation of tropical regions on Earth, such as the South American rainforest is the primary culprit of the release of carbon into the atmosphere (Schimel 2001)[22]. Coincidentally, lumber products "sequesters carbon for the life of the building" and is not released until the wood products are mulched or burned so as a

[21] Biomass or bioenergy is a clean and renewable energy source derived from the waste of humans and other natural processes.
[22] Tropical deforestation is responsible for an estimated 20 percent of total human-caused carbon dioxide emissions each year.

result 2.5 billion tons of carbon are stored in wood products contained in buildings and landfills (Falk 2010, 2-3).

It is hard to match wood in terms of performance, availability and overall environmental impact. It is not by accident that wood has been cultivated and used as a construction material since the beginning of recorded history. In that respect, wood also has enormous cultural and historical value to this country. In terms of overall sustainability, alternative products don't even come close. The amount of carbon produced to create concrete, steel and other building materials in comparison to wood is significantly greater (see Table 3).

Table 3: Net Carbon Emissions per Ton Produced of Construction Materials (source: Falk 2010)

Material	Net carbon emissions (kg C/t)[a,b]	Near-term net carbon emissions including carbon storage within material (kg C/t)[c,d]
Framing lumber	33	–457
Medium-density fiberboard (virgin fiber)	60	–382
Brick	88	88
Glass	154	154
Recycled steel (100% from scrap)	220	220
Concrete	265	265
Concrete[e]	291	291
Recycled aluminum (100% recycled content)	309	309
Steel (virgin)	694	694
Plastic	2,502	2,502
Aluminum (virgin)	4,532	4,532

[a]Values are based on life-cycle assessment and include gathering and processing of raw materials, primary and secondary processing, and transportation.
[b]Source: EPA (2006).
[c]From Bowyer and others (2008); a carbon content of 49% is assumed for wood.
[d]The carbon stored within wood will eventually be emitted back to the atmosphere at the end of the useful life of the wood product.
[e]Derived based on EPA value for concrete and consideration of additional steps involved in making blocks.

Value of Wood in the Landscape

In direct conflict with many of the tremendous attributes of wood as a construction material mentioned previously, wood has a particularly different existence in the landscape. Wood, of course, is biodegradable, which can be both good and bad. Nevertheless, it is prone to the deleterious effects of weather and the natural environment such as rot, insect damage and UV exposure (Lyons, 2007: Winterbottom 2000). While wood has low embodied energy relative to other materials, it performs poorly in terms of life cycle analysis (LCA) primarily because of its long-term maintenance issues (Crawford 2011). Wood is highly impermanent compared to other building materials like concrete and steel, and thus requires extra attention to treatment, durability, finishes, maintenance and appropriate application.

Wood has historically been used in the landscape for just as long as it has been used in general building construction. In the landscape, wood can be found in structures such as pergolas, gazebos, arbors, trellises, walkways, bridges, fences, gates, decks, docks, railings, entryways, seating, signage, planter beds and numerous other exterior items. Wood, being a natural material, can easily be used to create a specific aesthetic that connects the material to its site. In the 1800's *rustication*[23], or using the wood in its "most natural form" was an application first employed by Andrew Jackson Downing likely in attempt to link design (art) with nature (Winterbottom 2000, 10). Although a relatively simple concept, rustication (see Figure 11) widely influenced generations of landscape architects from Olmstead to the National Park Service (NPS).

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[23] Rustication is a building style used to create a more naturalistic, rural or picturesque built object in order to link human design and art to nature in stark contrast to the urban environment of the Industrial Revolution characterized by pollution and overpopulation.

Figure 11: A Sketch of a Rusticated Gazebo (source: Winterbottom 2000)

In addition to wood being a valuable green building material, wood's availability makes it also tremendously affordable, which is particularly important to landscape construction projects. Although lumber is by no means scarce, it is critically important to promote the use of native or local wood as well as Forest Stewardship Council (FSC) certified lumber that is sustainably harvested because it improves the quality of lumber resources (Thompson and Sorvig 2008). One major drawback (mentioned in previous sections) in conventional modern lumber is the fact that it is significantly lower in quality than its older growth counterparts as a result of cutting timber faster than it could develop. In the next two sections, wood waste will be explored as a material for landscape design and construction.

Value of Wood Waste as a Resource

For many reasons, wood is widely used in construction projects in the US. As a result, a lot of waste wood is generated and currently available for reuse. The EPA estimates that approximately 250,000 single-family homes are demolished each year in the US (EPA 1998). Much of this wood is from older-growth stock and is highly valuable because of its structural capabilities and aesthetic qualities. Of the 62.9 million metric tons of demolition waste created in 2002, 40 percent or 25.2 million metric tons was wood. Based on case studies, the Forest Products Laboratory (FPL) has determined on average 30 percent of demolition wood waste is currently recoverable[24], which equates to nearly 10.6 million metric tons according to 2002 levels (Falk 2002). Green building alternatives to demolition such as deconstruction, reuse and recycling has the capacity to divert large amounts of waste from the landfill and into new construction projects across the US. Although deconstruction requires more time and labor than demolition, the cost is often offset by the value of reclaimed lumber (Falk 1999).

Lumber grading (or re-grading) presents the most serious challenge to reusing wood waste in building construction. Currently local building codes in the US require a grade stamp for all structural components, which indicates grade performance standard, wood species and moisture content (Winterbottom 2000). Old stamps on reclaimed lumber do not qualify and thus need to be re-evaluated by American Lumber Standard Committee (ALSC) accredited lumber-grading agencies to meet

[24] Recoverable wood is a waste-industry term used to describe the total amount of wood that has potential to be salvaged or recycled but not combusted for fuel.

current building codes for use in structural situations. Re-grading salvaged lumber requires a third-party inspection of each individual component through stress testing and visual inspection, resulting in significant and mostly unfeasible costs. A study conducted by the Forest Products Laboratory (FPL) in 1999 concluded that nail holes and end damage accounted for a majority of grade reduction in reclaimed lumber (Falk 1999). Other organizations such as the American National Standards Institute (ANSI) and American Society for Testing and Material (ASTM) also create standards and performance criteria to evaluate numerous products and their construction applications (Falk 1993). Although reclaimed wood has many merits, conforming to national and local building standards is essential for the inclusion into the construction industry. Landscape architecture, which requires less structural components in its design and construction than architecture or engineering projects, is possibly better suited for wood reuse as a result.

Value of Reuse Wood in the Landscape

Reused wood is a preferred construction material, if available, in enhancing the performance of landscape structures. Ecologically speaking reused lumber is unmatched in its benefits to the biosphere. Reclaimed wood has the lowest embodied energy of all materials, significantly low carbon impact and it is usually a local product, which has many ecological, economic and social implications. Salvaged lumber can also potentially be harvested on-site, reducing the ecological footprint of a project and adding a layer of historical and cultural meaning to a project that can help inform the design process (Calkins 2000; Bennett 1999). In addition to added ecological, aesthetic and cultural value, using on site materials can also be a cost-effective strategy, as evidenced in park projects in Germany and Louisville, Kentucky[25] (Calkins 2009).

The largest impediments to reused wood in the landscape are the labor costs and intensity required in its procurement. If reclaimed lumber is harvested by the design or construction professional, labor and costs of salvage must be factored into the overall project costs. If the salvaged lumber is bought from a retail store, less labor is required; however, the cost of materials might be significant. Labor is essential to the bottom line of a project, because if it is measured incorrectly during the planning and implementation of a job, it can have substantial financial repercussions to a project. Choosing methods and materials that are relatively easy and less labor intensive to the reuse project are a part of every designer's learning curve. Equally important is the local availability or scarcity of reclaimed wood, which can have negative consequences as well (Calkins 2009). When a material is expended, there is likely limited options in finding a match or replacement, thus it is crucial to have enough salvaged material to finish a project (Calkins 2002; Calkins 2009). The size of the local salvage market might be a central determinant in whether or not to use reclaimed wood in the landscape.

Reclaimed wood and other materials also have a particularly strong presence in the Sustainable Sites Initiative (SITES), which is the landscape architecture equivalent to the LEED Rating System. SITES, though still a pilot program, ultimately provides

[25] Landschaftspark Duisburg Nord in Germany and Waterfront Park in Louisville, Kentucky both demonstrated aesthetic and financial savings in using on-site materials and structures.

direction and legitimacy for landscape architecture in the green building movement. Although LEED gives specific credits to materials reuse as well as building reuse, the material reuse credits have thus far been the most underutilized points within LEED (LEED 2008). SITES in contrast, has numerous potential opportunities for reuse points in a far greater range and less ambiguous tone than LEED such as the following: credits 5.3 Design for deconstruction or disassembly, 5.4 Reuse salvaged materials and plants, 5.5 Use recycled content materials, 5.6 Use regional materials, 5.10 Support sustainable practices in materials manufacturing, 6.2 Promote sustainability awareness and education, 8.2 Provide for storage and collection of recyclables and 9.2 Innovation in site design (SSI 2009).

The use of salvaged lumber in landscape design and construction is not easy. In fact, there are many factors that will potentially make reuse impractical such high labor costs, lack of available materials and durability concerns. This must be determined on a project-by-project basis. Although the reasons for reuse in the landscape are in some cases perfectly straightforward and obvious, there are many variables that can alter perceived benefits and consequently there are general ground rules to follow in order to make a project successful. In any event, the addition of salvaged wood in landscape projects has been observed by landscape architects and professionals, to greatly enhance the character and quality of a landscape design and construction project (Calkins 2000; Calkins 2002; Calkins 2009; Thompson and Sorvig 2008).

Barriers and Limitations to Reusing Wood in the Landscape

Although reclaimed wood offers tremendous benefits in waste reduction, natural resource conservation, decreased CO_2 emissions, economic savings, job creation and added cultural and design value, it also presents several formidable challenges. For materials reuse to be completely effective in producing the aforementioned benefits, many conditions have to be intact. Similar to any fledgling business, the reuse industry has to find its place in an already overcrowded design and construction job market. That being said, it is possible that reuse provides much needed "recession proof" alternatives to inefficient design and construction practices that have characterized the industry in the past.

One severe impediment to reuse as a design and construction tool is the lack of reform that has taken place in the cumbersome construction industry. In a similar way that the green building industry has struggled to inject itself into the design and construction business in recent years, the reuse industry must also navigate through hostile territory while generating support from stakeholders. A comprehensive study conducted by the Green Building Council of Australia[26] in 2006 to survey the green building industry, particularly in relation to supply chain management issues, found that lack of commitment from a number of actors along the supply chain created several problems for the efficiency and long-term sustainability of the green building industry (Zou and Couani 2012). Surveys aimed at getting answers from all industry professionals involved in the materials supply chain from the supplier to the designer

[26] The Green Building Council of Australia (GBCA) is the Australian equivalent to the United States Green Building Council (USGBC)

to contractor and client cited numerous inter-related issues ranging from lack of communication and coordination, high investment costs, slow approval processes and cost of testing products as primary culprits for green building materials and products to be implemented (Zou and Couani 2012). Whether there is a legitimate concern that reuse can adapt to the construction building materials industry, it apparent that fear of failure is a real problem for both reuse and green building.

Another serious concern for wood reclamation and its use in landscape design and construction as well as its broader implications for green building is the issue of labor. Wood reuse is a slow, laborious and meticulous process. Because of this, projects involving reclaimed wood require a design professional and builder with expertise in the subject; otherwise a project can quickly spiral out of control. The higher the cost, the less incentive there is for the designer and contractor to use the material. Identifying regular and reliable sources is key for landscape architects and contractors that use reclaimed material (Calkins 2009). Buying reclaimed material varies greatly from high-end salvage stores to community-based "re-stores." Harvesting buildings or reclaimed materials on site is another desirable option for designers and contractors that may simultaneously provide other design values (Calkins 2000). Careful planning and user experience are key determinants in the success of keeping costs down.

The final major impediment to reclaimed lumber in the landscape has to do with building codes and safety regulations. Three items are generally included in this issue: (1) building standards and code enforcement, (2) worker liability, and (3) safety regulations. Although reclaimed lumber is generally a stronger and more durable material, current building codes do not allow for its use in structural components, especially in structures deemed 'habitable' by building inspectors. National building standards require that reclaimed lumber possess the same grade stamp as conventional lumber, yet because reclaimed lumber has a variety of sources this is practically impossible. There is a way to address the quality control issues by re-grading lumber, usually through third-party inspection or by licensed structural engineers; however, this is extremely costly and usually inefficient (Falk 2004).

In addition to incompatibility with building standards, reclaimed lumber also presents a number of liability and safety concerns with its extraction and application. In the US, any house that was built before 1978 is assumed to contain lead-based paint (LBP) and as a result there are numerous federal regulations[27] that enforce the handling of such materials (EPA, 2010: Guy, 2000). Other hazards like asbestos and wood preservatives are known carcinogens and are commonly found within and comingled with reclaimed building materials. Dismantling buildings by hand from the top down also presents many safety challenges. Having liability and workers compensation is usually a minimum requirement for contractors but well worth it in case of a disaster.

Knowing how to pick the right job goes hand in hand with weighing the potential safety costs to workers. Similar to the financial costs of reclaimed lumber, it is essential to have trained professionals with proper safety equipment work with

[27] Environmental and worker health and safety regulations are administered by the US Environmental Protection Agency (EPA) National Emission Standards for Hazardous Air Pollutants (NESHAPS) and Occupational Health and Safety Administration (OSHA) as well as each individual states Departments of Environmental Quality (DEQ)

reclaimed materials to avoid the incidence of exposure to potentially lethal materials (Guy, 2000). No matter how many incentives are given to landscape design and construction professionals, the quality control and safety issues surrounding reclaimed wood create a hostile environment for reuse and severely limit its scope. Despite all of these barriers to feasibly reusing wood in the landscape construction and design, there are practical solutions to all of these problems and will be explained in further detail.

The Implications for Conventional and Reused Lumber

The central reason why suppliers produce, designers specify, contractors use and clients request conventional lumber in landscape construction projects is the same reason why people should advocate the use of reclaimed wood in the landscape: because it is a truly sustainable building material. Wood is not solely sustainable in context of the environment, but in terms of efficiency, affordability, availability and reliability as a product. The forest resources of the United States are vast and with the recent improvements in sustainable logging and forestry practices, American timber products will likely continue to be a trusted construction material.

Despite this, there are indications that the future is not so bright for conventional lumber products. It is still unclear what lies ahead for the American timber industry, one of the oldest industries in this country, still reeling from the housing bust and financial crisis. For example, in just four years, from 2005 to 2009, softwood production of timber fell by half from forty billion to twenty billion board feet (WWPA 2009). With the uncertain housing market, high unemployment, shaky global economy and rising price of fuel, conventional timber production could significantly suffer in the coming years. If this happens, the strong attributes that have sustained conventional lumber as an important commodity such as affordability and economic viability could falter.

The conventional timber industry and construction industry as a whole are at a turning point in their storied history. The green home building industry, which at the beginning of this millennia seemed merely a fringe movement is now a $17 billion dollar industry and expected to grow to $87-114 billion by 2016 according to the National Association of Home Builders (NAHB 2012). The timber industry has the potential to benefit greatly as a result of the rising green building activities simply because wood is not mined like other construction materials. Sustainably harvested forest products are now widely available and home-improvement retail giants like Home Depot have vowed to only sell sustainably certified lumber to customers in a monumental effort of environmental stewardship (Thompson and Sorvig 2008). Organizations like the Forestry Stewardship Council (FSC) and the competing Sustainable Forestry Initiative (SFI) certify that timber products are sustainably harvested, through improved management techniques like "shelter-wood cutting" and the introduction of waste-reducing sawmill tools, which the US Forest Service estimates reduces wood waste by 33 percent (Thompson and Sorvig 2008).

As most of the old growth forests are long gone, and the quality of lumber continues to decline, the need for sustainably harvested timber production techniques is increasingly important to the future of wood as a renewable resource and viable construction material. Conventional lumber has its merits as a sustainable construction material, that is, if it is harvested responsibly but where does wood reclamation fit in? Can reclaimed and conventional lumber peacefully coexist?

One considerable factor regarding the future of conventional lumber yet to be seen is the effect that reclaimed lumber potentially has on the traditional timber market. With the projected rapid expansion of the green building industry and increased awareness to waste management issues, the development of the reuse industry is likely imminent and could play a significant impact in complimenting forest industries by reducing strain on forests and subsequently increasing the quality of timber production. However, it could also be seen as a competitor to the already struggling timber business. Regardless it is important to recognize that the increased use of salvaged lumber in collaboration with sustainable forestry practices could possibly determine the long-term viability of wood products as a whole.

For centuries wood has been an immensely reliable building product and fundamental to the development of this country. Although most of the high-quality, old growth lumber has long been cut, an incredible amount is found in this nation's building stock. As an increasing amount of designers within the green building movement have become concerned with the life cycle of building materials (from production to end-life), green building alternatives to demolition such as deconstruction and materials reuse have the potential to harness reclaimed materials for the use in landscape design and construction projects to add ecological, economic and cultural values. Reclaimed lumber has many potential benefits to landscape design and construction projects but is it truly feasible in comparison to conventional building materials? For example, can reclaimed wood overcome issues of labor and cost associated with its procurement and application? Are quality control issues relating to structure, durability and energy performance major faults in its dependability as a building product? Does reclaimed wood provide a comparable product to conventional wood products?

CHAPTER THREE:

METHODOLOGY

Testing the Built Product

As previously outlined, the central objective of this project is to design and construct wood landscape products with the purposes of exploring how reuse can best be integrated into the design and construction industry. There are many apparent impediments to the overarching goal as evidenced in Chapter 1 and Chapter 2; however, for research to progress, emerging ideas need be explored with careful thought and practical experimentation. In this case, the built product is the most visible way to examine how wood materials can be effectively reused in landscape construction. For this specific study, products will be evaluated (in survey form) through the eyes of design professionals who deal with clients, contractors and materials on a regular basis. The built product not only provides a tangible comparison for outside reviewers but also allows the researcher to go through the experiential process of physically constructing each item and making design decisions. Whether ultimately beneficial or detrimental, these design decisions are useful in the prototyping process and learning lessons from the construction process are critical to the development as a professional. Additionally, the intent of this methodology, study and thesis is to use the experiential built product and survey results in tandem with knowledge gained from the current body of literature in the previous chapter to generate an overall conclusion on the feasibility of reused wood in landscape design and construction projects.

Framework

The central framework for this research project is to build (from reused wood) three different common landscape items; the tool shed, fence and gate, and raised bed, which are all commercially marketed products found in the typical homeowners' backyard or run-of-the-mill community garden. The commonality of each item is fundamental to the research of this project because it represents the "mainstream" culture that is the driving force behind the construction industry. In order to make worthwhile strides in reforming the hulking industry of construction, and for the general population to ultimately embrace reuse, considerable understanding of the market and people who buy goods and services, must be established. Is the reused product marketable or comparable in price to the conventional good? Therefore, this research uses common landscape items as tools or vehicles for examining change and whether products made from reused wood can effectively work in a competitive market.

Wood Waste Types

In addition to the three common landscape items, each item will be built in three different variations of wood waste. As outlined previously, the extensive use of wood in the United States results in a tremendous amount of wood waste in many different forms. In 2002, nearly 63 million metric tons of wood waste was created as a result of the manufacture of a variety of different types of wood-based products (Falk

2004). The point of this exercise is to explore different methods for achieving the same goal of reuse by looking at an array of different types of wood waste that are available. Another point of this procedure is to find reuse for overabundant items such as the pallet, which represent a significant part of the waste stream. Although solid wood recycling has grown tremendously since 1990, reuse of "recoverable" or salvageable wood has often been underutilized.

Wood Scraps – less than Four Feet

The first wood waste type to be evaluated is wood scraps less than four feet in size (see Figure 12), which is a wood waste that can be found in both residential MSW and C&D waste streams. On average, the National Association of Homebuilders estimates forty percent or three thousand pounds (1.5 tons) of waste on a new home construction site is wood waste (Falk 1999). Much of these are end cuts or scraps created from framing and trim work in wood frame construction. A quick investigation into the typical on-site dumpster at a new construction site will demonstrate this. The drawbacks, of wood scraps, is that the size limits the types of application for this product. Nonetheless, this type of wood waste is overabundant and its creative reuse is worth exploring. Determining whether reuse of wood scraps is more beneficial than the burning of wood scraps for fuel or mulching of wood scraps for landscape application is something to be explored.

Full Length Dimensional Lumber

The second type of wood waste in this project is standard reclaimed dimensional lumber at full length (see Figure 13). The primary source for this type of wood is demolition or renovation sites. In 2002 alone, 5.6 million metric tons of wood waste was created “at repair or remodeling sites” of which 3.8 million metric tons was “recoverable” (Falk 2004, 35). In contrast to the other two material types used in this study, the standard full-length dimensional lumber is most comparable to modern, store bought lumber in that it has similar length and overall appearance. There are however, many differences, chiefly with respect to the variable age of reused lumber, which in turn affects density, weight, nominal or true dimensions and aesthetic characteristics to name a few. The full length reused dimensional lumber, though clearly different from new lumber, is important in this research because it potentially is the most similar alternative to new, conventional lumber.

Figure 12: Wood Scraps Created in the Construction Process (source: Author 2012)

Figure 13: Full Length Dimensional Barn Lumber Loaded on a Trailer (source: Author 2011)

Figure 14: Fence Constructed with Pallets (source: Author 2011)

Wood Pallets

Aside from wood products being used for fuel consumption, the wood pallet (see Figure 14) is the largest domestic user of wood based fiber in the United States (Marshall and Hamner 2005). Practically unnoticed by the outside world, the wood pallet is responsible for moving the world's products to commerce and in 1998 alone more than six billion board feet were used to construct 441 million new hardwood and softwood pallets (McKeever 2002). As a result, the wood pallet is a significant part of the MSW and C&D waste stream.

Recycling of industrial wood pallets represents a one of the most successful aspects of wood recycling; for example, 299 million pallets were recovered for recycling in 1999, resulting in the diversion of seven million metric tons from the MSW waste stream (Falk 2004). A few reasons for the increase in pallet recycling was that new pallet producers in the 1980s and 1990s began responding to the increased cost of materials, cost of land filling and increased environmental awareness (Bush, Reddy and Araman 1998). Thus, both pallet producers and landfill operations recycle pallets to make new pallets and grind up pallets to produce fuel and mulch in order to offset costs and increase efficiency through waste diversion. Despite this, only 14.8 percent of total pallets are recovered from the MSW waste stream compared to paper and paperboard products at 65.5 percent and 63.1 percent of steel (EPA 2008.)

In addition to recycling, another significant and recent shift in the pallet industry has occurred, where pallets are recovered, repaired and reused as is, typically selling for 25 to 50 percent less than new pallets (McKeever 2002). In 1998 there were an estimated 250 million pallets recovered and repaired, 185 million more than in

1992 (McKeever 2002). Similar to this idea, reusing palettes with minimal alteration was the rationale in selecting the wood pallet as the final reused material in this research project. As is the case with the other two wood types in this study, the advantages of reusing pallets as cladding versus recycling pallets into mulch and fuel is a central part of the research.

Design Criteria

The final component of the methodology is developing design criteria in order to grade each landscape structure, either reused or conventional. In order to best gauge the product, five key measures for success are presented in survey form. These criteria are aesthetics, affordability, durability, efficiency and ecological impact. Each of these stand-alone values represents both qualitative and quantitative factors that are important in the performance of well-designed products. A product could potentially exhibit none of these values or all of these values. For the purposes of ranking and analyzing each landscape item, each measure is ranked from one to five by respondents, one meaning the particular item is least effective and five meaning the particular item is most effective.

In order to have a comparative analysis of the reused product with the new, conventional product, all three landscape items evaluated have three reused models labeled as ‘A’, ‘B’ and ‘C’ as well as a new, conventional product labeled as ‘Lowes.’ Landscape items labeled as ‘A’ utilize the reused wood scrap material, items labeled as ‘B’ use the full-length dimensional reclaimed wood and items ‘C’ are made from pallets. The landscape items labeled ‘Lowes’ are selected comparison products marketed at the big-box home improvement retailer, Lowes Corporation. A supplemental data sheet is provided to study participants to assist in the quantitative assessment criteria such as affordability and efficiency. A sample of the survey, as well as completed surveys are located in Appendix A and Appendix B, respectively.

Aesthetics – Is the Design Marketable?

Aesthetics is a qualitative assessment that is variable to the reviewers' personal opinion; however, it is an essential part of why products sell. For the sake of this study, design and construction professionals' were chosen to be reviewers because they have a keen eye for selecting materials and play a role in determining or facilitating their clients' tastes. As styles and tastes continually change, aesthetics may not be the most effective measurement for the feasibility of reuse, but it is no doubt a critical part of product design and marketing. Although reclaimed wood is more often than not associated with a rustic and worn style seen in vernacular architecture, a minimalist approach, to construction application, for example, can dramatically influence a more contemporary look to salvaged lumber, thus the method of application is highly determinant in aesthetic style and should not be overlooked.

Affordability – Is the Pricing Competitive?

Affordability is a quantitative value in this study that factors in labor cost, both the amount needed in construction of the product and salvage of the materials, as well as a value assigned to the building material. A data sheet was provided to study participants showing the estimated price of each landscape item to compare with each of the ‘Lowes’ items. Affordability is significant in that it determines how accessible a product is, how competitive it will be to similar products and whether the product will move on the sales floor.

Durability – Will the Materials Last?

Durability is an assessment that has many facets. This judgment plays more in favor of professional experience and knowledge of material types and applications, which is strong reason for having a panel of experts acting as participants in the study. Time, which cannot be measured in this study, plays a major factor in the degradation of wood (Thompson and Sorvig 2008). Wood is ultimately biodegradable but some wood types are more rot-resistant than others such as cedar and cypress. Older growth lumber has a higher density than newer wood products, which make it more resistant to the deleterious effects of weathering. The application of wood may also play a part in how fast or slow wood declines; for example, if wood has ground contact or not, or if wood has areas that collect water easily. Participants’ knowledge of these types of materials, types of applications and general experience in the effects of time on materials plays a significant role on this assessment.

Efficiency – Does it Maximize Waste?

This measure similar to affordability is a quantitative assessment involving several factors such as the time and cost it took to build the item, source of materials, amount of waste diverted or reused, raw weight of the products and embodied energy used to produce the item. An efficient product is one that is judicious when considering all of the above factors. Good project managers are very aware of efficiency and how it can positively or negatively impact a job. Efficiency is somewhat complex and can be judged using different methods but as with other factors, data is provided to jurors so they can make a reasonable determination using both raw numbers and professional experience.

Ecological Impact – Does it reduce footprint?

The final assessment included in this study is an overall gauge of the landscape items' ecological sustainability. Wood is generally considered a sustainable construction material as a result of its low embodied energy, being a renewable resource, widely available, relatively cheap, easy to work with and even the fact that it is biodegradable. One product may result in a higher diversion of waste materials yet still have a higher embodied energy as a result of the extra labor associated within the production phase. Efficiency and durability ratings both potentially factor into the overall ecological impact as one product might be made using significantly less labor and consume less energy but another might be made from a material that could last much longer in the landscape. A product that is excessive in weight might require heavy equipment to move and transport thus increasing the reliance on fossil fuels. The method of material application might be highly inefficient and difficult to install but aesthetically superior, so these factors must be weighed accordingly. Subsequently, there are many variables based that must be considered to determine a products' ecological impact, but similar to the other four criteria this assessment is based on a mixture of qualitative and quantitative data as well as the designer's professional opinion and experience.

Quantifying Reuse

In addition to the set design criteria for evaluation, supplemental quantifiable data was provided (see Appendix C) to assist in the decision-making process of the study participants. A sheet of the following data was provided along with the study survey with the following key quantities: estimated cost, structure weight, embodied energy ranking, material source, dimensions, building envelope linear footage and total linear footage. Some quantities such as cost, embodied energy, material source are more relevant to the study criteria than other data such as structural dimensions and weight. Two additional data, material type and age, are included in the data sheet because they are factors in terms of determining the life span or durability of a product, such as the difference between treated and untreated lumber or hardwood and softwood.

Estimated Cost

The first variable for measuring the feasibility of reclaimed wood products is estimated cost. In terms of calculating cost, a reuse project is substantially different from a typical construction project in that it requires the process of salvage in addition to construction. There are numerous disincentives that affect estimated cost such as increased labor, turnaround time for salvage and reuse and stringent regulations for salvage workers, all of which present a serious challenge to the process of materials reuse (Falk 2002). A successful reuse project must carefully weigh the cost efficiency of salvage and reuse conjunctively, which can be significantly more complicated and labor intensive than general construction.

In this study, an *aggregate*[28] of three separate data were used to determine estimated cost; estimated time and cost of construction, estimated time and cost of salvage and cost of materials. As the construction trades have highly variable skill levels and hourly rates, two equivalent and interchangeable alternative hourly rates are used to find the estimated time and cost of construction; one highly skilled wood worker such as a *master carpenter*[29] at $40 per hour or two semi-skilled *journeyman*[30] or *apprentice*[31] carpenters at $20 per hour. The assumption is that one master carpenter can accomplish the same task in half the time and garner twice the pay. The trade names and associated rates above are specific to the wood working industry but rates are highly variable according to location. In this case rates were based on averages determined according to the study designer's experience working in the construction trades in the Southeast.

The next element of estimated cost is the time and cost of salvage or procurement of salvaged materials. In many cases, reuse building projects feature an amalgamation of different construction materials of various sources, types and age. This is especially true for this project. Just as a general rule of thumb, the safe

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[28] A whole formed by combining several (typically disparate) elements

[29] A craftsman fully qualified to practice his trade and to train others in it

[30] A trained worker who is employed by someone else

[31] A person who is learning a trade from a skilled employer

dismantling of a building by hand, with proper planning, can be done as quick as it would have taken to construct the same building; however, when the processing and cleaning of salvaged materials is included, the amount of time involved in the salvage process can be greatly higher. Unsafe buildings, excessively nailed materials and hazardous materials can significantly alter the cost efficiency of a salvage project, thus is the reason for careful selection of a salvage project.

The materials used in this project were donated by the *Material Reuse Program*[32], operated by the author, and as a result of the variability of materials, sources and labor methods used (by contractor and volunteer), the cost of salvaging was deemed by the author to be on average equal or less than the cost of construction. For the purpose of estimation a standard laborer rate ($10 per hour) was assigned to the total hours of salvage.

The final variable in estimated cost was the cost of materials. This number includes the cost of salvage materials with the cost of new material, in most cases, hardware. For cost of materials, three standard rates were assigned to both the framing and envelope according to quality and type of building materials such as modern softwood, historic hardwood and old-growth softwood, at 0.50 per linear foot, 1.00 per linear foot and 2.00 per linear foot respectively. The value assigned to materials and labor in this project is based on the estimated market value and the

[32] The Material Reuse Program is a student-run deconstruction and reuse program located at the UGArden farm on South Campus, created by the author in 2011 to divert construction materials from UGA and other local construction projects for reuse in community-based projects. The program website is www.thematerialreuseprogram.com.

author's past experience in the deconstruction industry; however, it should be noted location is a huge determinant in cost.

Lumber Weight

Similar to cost, each stick of lumber has an associated weight, thus in order to get an accurate picture of individual landscape items' weight, each piece must be individually weighed and totaled. This is important because reclaimed lumber, like older growth Southern Yellow Pine, with a heavy amount of pitch, latewood or heartwood weighs substantially more than conventional lumber made from primarily from pulpwood.

The weight of each landscape item has a significant role in the marketability, efficiency and subsequent feasibility of reused materials as a landscape item. An extremely bulky piece of outdoor furniture for example is less attractive than a lightweight version that can easily be folded up and moved around. In the case of the tool shed, a model that is too heavy could be detrimental to its installation and function as a prefabricated unit. Weight has a strong correlation with embodied energy because the volume of a wall typically has a higher embodied energy cost (Thompson & Sorvig 2008). Making sure each building part has a specific function and eliminating unnecessary components is essential to the design of each landscape item.

Embodied Energy

One important concept in the analysis of the life cycle of building materials is a concept called embodied energy referring to all the energy used in the manufacture and production of a building material or item in its entire life from the origin as a material to its installation as a product (Thompson and Sorvig 2008). The life cycle of a material also carries an operational and disposal footprint but this is not traditionally factored into basic embodied energy. The entire production, transportation and installation process; however, is a part of embodied energy calculations and serves as a general rule for pollution emissions. Embodied energy is "usually expressed in terms of energy per unit of product, just as cost estimates are based on cost per quantity (Thompson and Sorvig 2008, 279). The standard unit for this calculation is measured in BTU's or British Thermal Units.

Embodied energy is a helpful tool for environmental designers weighing the environmental costs of materials. For example, wood has generally the lowest embodied energy per unit compared to steel, which is relatively high. In addition, a designer should not overlook the structural quality or durability of building materials as well. Another beneficial aspect of this measurement is getting environmental designers and builders to think critically about where materials come from and how it affects society as well as environment.

An eight-foot stick of exterior grade, treated Southern Yellow Pine 2x4 undoubtedly begins its lifecycle in the forest, often times, a pine plantation, where it is grown for a period of thirty years or so and harvested. The mature tree is felled, bucked and skidded to a log truck, loaded and carried by log truck to the mill, unloaded, stacked, milled dimensionally, dried or treated, graded, banded and shipped to a retail store. There are many variables involved such as how far the material traveled from its extraction site, how much energy was used and emissions created in the production process and how many workers were involved in the extraction, production and transport of the material (see Table 4).

As previously mentioned, wood generally has low embodied energy compared to metal or plastic products, which are resource or production intensive, but reclaimed wood has the lowest embodied energy because the traditional production process is skipped. Instead the extraction method or harvesting of salvage materials is injected as part of the "production" process and energy calculations. Regardless, manual deconstruction or salvage of reclaimed wood would create much less CO2 emissions or energy consumption compared to the process of the traditional harvesting of timber. However, this of course, hinges on the source of reclaimed materials.

For the purposes of limiting confusion for the study participant the totals of embodied energy are ranked for each reuse item in comparison to the conventional 'Lowes' item (see Appendix C). The embodied energy totals (see Appendix D) were estimated using the "basic embodied energy" calculation provided in Thompson and Sorvig's *Sustainable Landscape Construction* text. The featured 'Lowes' items were approximated in terms of embodied energy in tandem with source and type of wood product, but it must be explained that this is a rough estimate as the production process for Lowe's includes multiple vendors and parties and due to time constraints a solid calculation would be difficult to ascertain without considerable resources.

Table 4: Embodied Energy of Construction Materials (source: Thompson and Sorvig 2008)

Embodied energy of selected landscape materials by volume.

Materials by Volume	*CSI*	*AvgEst Btu/Cu Ft*
Concrete, ready CF	3.1	96,100
Concrete, ready CY	3.1	2,590,000
Lumber, hardwood	6.0	9,820
Lumber, softwood	6.0	8,555
Lumber, glue-lam beams	6.1	15,611
Lumber, plywood	6.1	14,883
Lumber: Roughsawn	6.1	495
Waterproofing, asphalt	7.1	8,639
Insulation, rigid polystyrene	7.2	15,300
Paint, exter oilbased	9.9	488,264
Paint, exter waterbased	9.9	489,032
Stains & Varnishes	9.9	503,668

In addition to using basic embodied energy in the calculation of energy other models are available such as the EPA Waste Reduction Model (WARM) and Life Cycle Assessment (LCA). The EPA WARM tool provides the carbon dioxide impact of waste reduction through energy units (million BTU) and metric tons of carbon dioxide equivalent (MTCO2E). As a result of the relatively small size of project, the WARM method is likely out of scale as it is typically used to forecast waste emissions in larger operations such as landfills. Another flaw in the WARM model is that it is only useful in comparing a "baseline scenario" or common practices of waste management (such as landfilling, combustion, and recycling) against an "alternative scenario" (such as reuse or source reduction). Instead of comparing reuse wood to conventional wood in terms of energy efficiency, the WARM model demonstrates how much emissions savings are available through wood reuse alone. The findings of the WARM projection will be discussed in Chapter 4 and presented in Appendix E.

It was determined that Life Cycle Assessment (LCA) was incompatible with this particular project, thus it was not used. LCA is possibly a more accurate tool than embodied energy; however, it has limitations. As noted in previous paragraphs, there is difficulty in using LCA in landscape construction as it mainly focuses on buildings (Thompson and Sorvig 2008).

Material Source

Since the embodied energy of the 'Lowes' item is difficult to determine, the type and source of materials are approximated; for example, since Western red cedar is used in the 'Lowes' tool shed, it is assumed that the material type comes from the West Coast (Eugene, Oregon for this project), where that material is typically harvested. This would significantly increase the embodied energy due to transportation costs of freight in such a large distance (more than 2000 miles from Athens). In contrast, most of the salvaged lumber used in this project comes either from buildings on site or within a twenty-mile range. Theoretically, the embodied energy for reclaimed wood in this project considerably undercuts the 'Lowes' items, which are manufactured and shipped cross-country.

Dimensions

Each landscape item – tool shed, fence with gate and raised bed – have similar dimensions according to type. The reason for this, of course, is to easily analyze item for item measurements (such as weight or embodied energy). The three tool sheds made from reclaimed wood, for example differ only by one square foot compared to the 'Lowes' cedar shed. Since all tool sheds have practically identical dimensions, they are easy to compare in different aspects. Each dimension was spelled out for the study participants for reference and a reminder that each item is comparable.

Total Linear Footage – Building Envelope

In contrast to the dimensions of each landscape item, the models 'A', 'B', 'C' and 'Lowes' are dramatically different in terms of envelope materials and application. As mentioned previously, the reason for this is to test different types of reclaimed wood waste comparatively with conventional lumber. Additionally, the total amount of material and thickness also factors into labor costs and embodied energy significantly.

Total Linear Footage

The total linear footage used in construction, which is the total of framing lumber plus lumber used in the building envelope or cladding, is more importantly a figure of how much material was salvaged or saved from the landfill. Although the more material salvaged in a structure could be seen as having more environmental benefit, the more cumbersome or heavy a structure also creates a higher embodied energy and labor cost. The three models of landscape items have significantly varied totals in terms of total linear footage, which affects their appearance, labor and energy cost. An eight-foot fence section that uses twice the amount of lumber as its comparison model could be seen as having half the energy efficiency or being twice as costly.

Material Type and Age

In addition to the quantitative data provided, two specific qualitative factors were included in the data sheet because of their relation to structural stability and durability. Wood of different ages and types vary greatly in response to weather conditions. Climate also plays a significant role in the tendency for wood to decline as well as treatment type. In this project, all wood is left untreated from its original state so material type is important. An old growth piece of pine similar to a mid-century piece of hickory (hardwood) is dense and therefore rated strong structurally and relatively resistant to weather, or water and UV exposure. One usually overlooked aspect of reclaimed wood is that wood eventually dries out and loses a significant amount of its moisture content making it less structurally integral and more susceptible to dry rot and insects. In addition, considerable testing at the Forests Products Laboratory has assessed that the frequency of nail holes significantly affects the structure of a piece of wood (Falk 2006).

Modern softwoods like pine and spruce, depending on their size, are particularly susceptible to the deterioration of weathering, especially when ground contact is made. Pressure treated modern wood, on the other hand, has a reasonable degree of durability, though all wood is ultimately biodegradable. As mentioned before, time is one limitation to this study, so professional opinions regarding the material type and application of wood are the basis for this estimation and not scientific data.

Data Collection

During construction of the Reuse Village, the site was photographed and documented daily through construction notes and observations. Each piece of building material was counted and weighed during the construction process as well. The quantitative data collected was then used in the determination of energy calculations such as embodied energy and WARM forecasting, for example. Construction notes, sketches and other observations are helpful references in this and other projects in understanding the process.

Evaluating the Project

After construction was completed, study participants were invited to attend the evaluation where they reviewed all built products in comparison to the selected 'Lowes' model. Participants were asked to complete one form per each zone, and rank all three landscape items according to the five criteria (see Appendix A). The fourth and final form is dedicated to ranking all three comparison items with the same criteria. A data sheet with quantitative and qualitative information was provided to supplement the decision-making process for participants (see Appendix C). Each participant brings a different background of experience that ideally will result in varying answers and opinions on the survey form (see Appendix B). The study survey represents the first part of "tangible" evidence provided in this report; the other part being the experiential evidence discovered through the construction process. Results of the study findings are explained in Chapter 5.

Study Participants

Although the survey size of this study is small and the range of participants is narrow, the point of the study is to get a careful and thoughtful snapshot of each item through the view of the construction and design professionals. Later studies could possibly engage community members, student groups, or other focus groups, but for the purposes of designing and ranking newly introduced prototypes, this specific group is more beneficial in the development and design phase of such a project because they are people that deal with clients that would potentially buy items made from reclaimed materials.

The six design and construction professionals are composed of two tenured design faculty with backgrounds in landscape construction and sustainable building respectively, one senior designer at the Office of University Architects, one materials research scientist with the EPA, one University administrative director who oversees campus landscape construction and one private contractor who has worked in building construction for thirty years. Each of these construction and design professionals carry decades of experience with large capital projects, construction management, research and education within the green building industry and have been mentors to countless numbers of students at the University. As each participant of the study is to remain anonymous for their protection they will be assigned the following generic titles: Design Faculty I, Design Faculty II, Design Professional I, Materials Scientist I, Construction Administrator I, and Construction Professional I.

Limitations

A major limitation to this study is its small sample size due to time and cost constraints. Another limitation is its narrow range of sample participants in terms of background and demographics. The aforementioned explanation for the limited range is merely for the purposes of getting qualified opinions from local design and construction professionals that understand project management and real-world issues in design and building as well as have a similar experience level with emerging green building practices. Having a mixture of faculty, design professionals and construction managers ensure a less biased and more balanced take on practical application of conventional versus experimental construction techniques and philosophies. Although inferences can be made between the small building project and larger structural issues of the construction and green building industry, the overall goal of this project is to look at issues from a much smaller scale.

Experiential Evidence

One key concept of this study is to gain knowledge from the process of building. A construction project in design or theory is often much different from the actual implementation. Mastering the construction process comes with experience, but all results of a construction project, whether good or bad, are lessons learned. The technical notes and hard data provided in the next chapter are useful in documenting the process and evaluating specific factors. A daily journal of the construction project was kept and provided hard numbers and evidence of how the reused wood worked well and how it struggled throughout the implementation process. There were a few central points regarding the experience of designing and constructing the Reuse Village that were realized during the construction process and will be fully explained in Chapter 4 in accordance with the five design criteria in addition to the author's reflection of overall product feasibility. The other aspect of this study is to balance the experiential evidence learned from the built project with professional opinions examined as a result of the survey. The difference is that experiential evidence allows assessment of the findings over a long period of time (as long as the study exists) whereas the survey is merely a snapshot of time and could vary depending on changing personal tastes and depth of sample size. Nevertheless, the intent of this study is to gauge the feasibility of reused materials in the landscape through the two methods of experiential evidence and opinion-based survey as well as an analysis of the current body of work.

CHAPTER FOUR:

IMPLEMENTATION

The Building Project

The physical construction project of the nine landscape items broke ground in late March and took roughly 30 working days to complete. This collection of landscape items was constructed at the UGArden on South Campus and represents the gist of this study: to analyze the feasibility of reusing wood in landscape design and construction through a tangible, built project. Can reused wood function in the landscape comparable to new materials of the similar nature? Is reclaimed wood a proper alternative to conventional materials? Can this be proven? The built project, dubbed the 'Reuse Village,' will hopefully answer some of these questions.

One major theme and goal of this chapter is using practical and experiential knowledge as a resource for understanding the process of reuse, including its drawbacks and benefits. This chapter, adding to the previous chapter on methodology, is a written documentation of the construction process from pre-planning to final product. As mentioned in previous chapters, the "tangible evidence" of this project is two fold: the first is the experiential evidence as documented in this chapter (including observations on material application and hard data), while the other is survey results based on professional opinions featured in the next chapter.

Additionally, using strategies and knowledge from the current body of literature on this subject is another method and apart of the underlying methodology of this thesis in determining the feasibility of reuse in landscape architecture.

Pre-planning

A large part of a reuse project involves careful planning and development of a sound framework for construction, but most importantly, a plan for acquiring and selecting materials for reuse. There are various ways to go about a reuse project. Many landscape architects well versed in reused materials such as Meg Calkins recommend, "letting materials inspire the design" (Calkins 2002, 38-41). Another important decision to be made with reclaimed lumber is making sure you have enough (or extra wood) to complete each part of the project; because when the material runs out, finding a similar material could be difficult or impossible.

The preferred method in this project was to design the products with a general understanding of what materials are available in the local environment. In this case, the raw construction materials had already been salvaged from *various locations*[33] and completely processed of nails and other debris. The common items found in salvage in the Athens region are softwoods like longleaf and loblolly pine and hardwoods like hickory and oak. Standard dimensional lumber, sheathing like plywood and flat board, as well as flooring are the most common types of reclaimed wood.

[33] All materials came from within a 35-mile radius, and most (95 percent) came from within a 20-mile radius.

In addition to procuring materials, developing a site plan for the location of each item is crucial to organizing and presenting the project study. In this case, all of the three landscape items – tool shed, fence with gate and raised bed – is featured three times over in three separate zones (A, B and C), where each zone focuses on the one of the three chosen waste wood types (see Figure 15). Beginning with zone 'A',

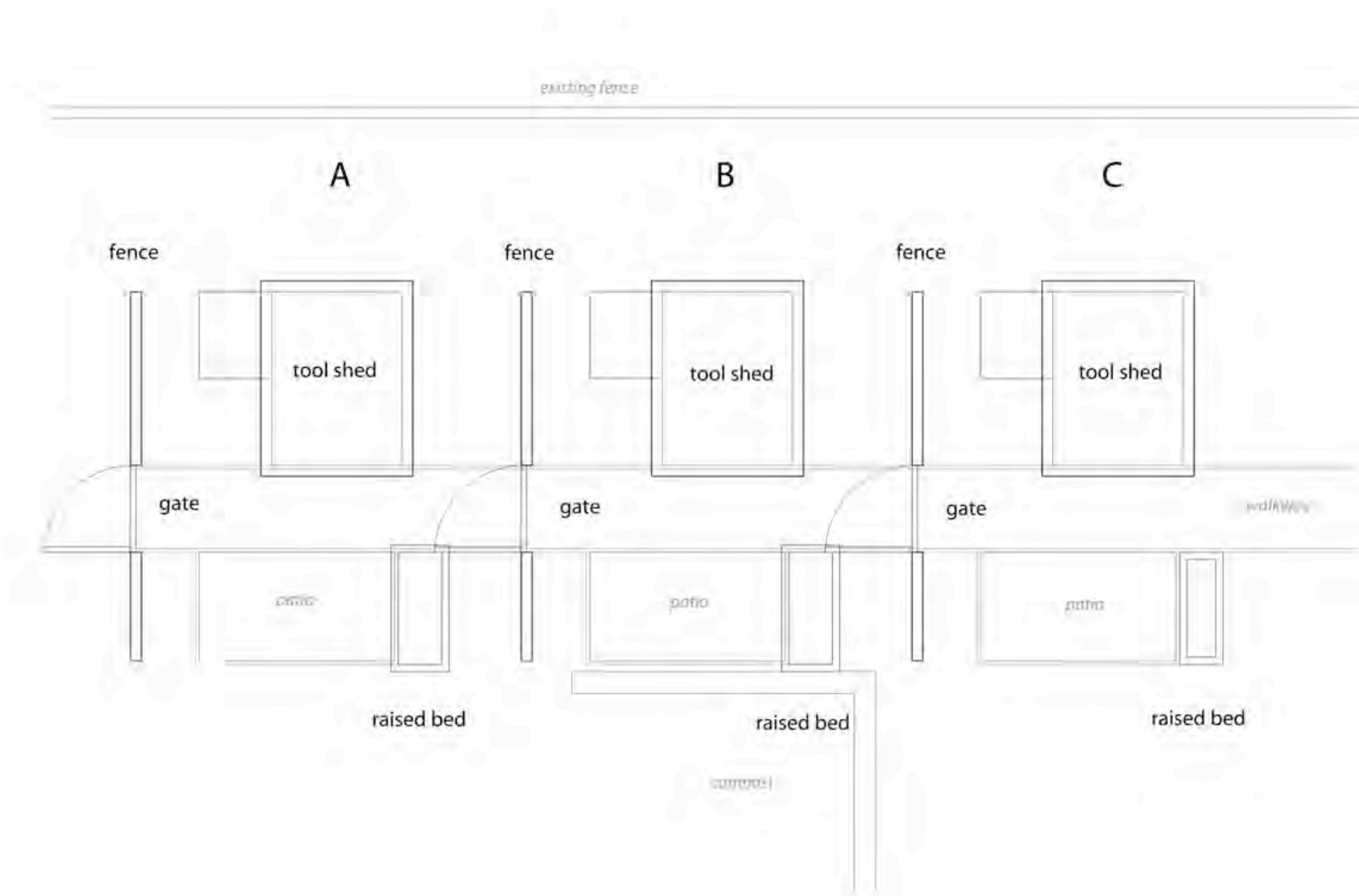

Figure 15: Reuse Village Site Plan (source: Author 2012)

each item is comprised of wood scraps less than four feet. Next, zone 'B' features items made from full-length barn dimensional lumber and finally all items in zone 'C' are built from pallets. Similar to a demonstration area at a home improvement retailer the sectors were stacked one after the other, as if it were its own village with a central path that connects each set of items with a fence and gate subdividing each zone. Similar to any community, each zone featuring its own trademark material individually exhibits its own character and aesthetic.

Once each item is arranged logically, drafting each prototype according to proven building standards is important to be able to scope the right amount of materials needed for the project. Designing the structures down to every screw and bolt will alleviate any material concerns early on so that if there is an issue it will be dealt with early on in the process. In the case of the tool shed, a framing plan is key in determining the amount and types of dimensional lumber that is needed throughout the project. Following local building codes and standards is also critical in this project for the ultimate goal of assimilating reuse building processes into the modern construction industry. Although Clarke County neither requires a building nor fire inspection for a 'non-habitable' building less than 144 square feet, this varies from place to place. Designing a tool shed that is too big has numerous implications for potential users of products such as extra fees for permits, more demand for materials and associated costs and the *structural implications*[34] of using reclaimed wood. Developing a model that is easily constructed as well as feasible in terms of size is

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[34] According to local building codes, a 'habitable' structure requires grade-stamped lumber. As mentioned previously, re-grading lumber is required for reuse lumber in structural applications.

important in the adaptation of a prototype with a widespread market and is why so much scrutiny must be placed in the design.

Standardized Display

In accordance with designing and building a presentable demonstration community, equally important is using uniform displays. This includes making identical platforms for each tool shed, similar treated fence posts for each fence line, analogous pavement patios for future seating, homogenous framing for sheds, comparable structural forms and roof pitches. In the same way that the site plan arranges space for the study participant to focus on each individually unique wood waste type, the standardized display frames each item in an unpretentious manner. Finally, in harmony with the overall reuse project, every material used in the construction was fabricated with reclaimed wood and other reused building products (from posts to platforms to pavers).

Material Harvesting

All reuse projects vary greatly in terms of material procurement; nonetheless it is an integral component of the reuse project. Although most of the materials in this project were harvested well before the commencement of construction, it is important to recognize where the chosen materials came from. First, all materials used in this project were harvested locally, that is no more than thirty-five miles in distance. As mentioned in earlier sections, this plays a major role in cost and energy efficiency of wood used in this project. Reclaimed materials used in this project came from four major sources, which will be explained in more detail in following sections: (1) on site deconstructed buildings, (2) on campus salvaged buildings, (3) private deconstructed buildings and (4) trading between other builders. All material was salvaged as part of the Material Reuse Program between May 2011 and May 2012. Students and volunteers working for class credit, class projects or community service hours, were responsible for assisting in the process of deconstruction and salvage; processing, stacking and storing the materials at the UGArden barn (see Figure 16).

Figure 16: Students Assist in Barn Deconstruction (source: Author 2011)

Material Selection and Application

Zone 1: Wood Scraps

In the first zone, wood scraps were the substrate for the cladding of the fence panels, gate decking, tool shed envelope and the entire body of the raised bed. Tool shed 'A' features a typical 2x4 platform stick frame composed of a mixture of air-dried and kiln-dried lumber with a cantilevered tin shed roof and naturally lit open clerestory (see Figure 17). The significant difference in this structure from similar shed roof outbuildings is that instead of blocking and siding, the interior cavities of the frame were filled with wood scraps. Plywood sheathing made from 1960's grade Japanese Ash provided shear stability for the interior structure while providing a clear edge to stuff the scraps into. Wood scraps were an assortment of various dimensions, mainly 1x4 and 2x4, but of a variety of ages, colors and treatments, resulting in a patchwork ensemble of vertical stripes. Because time will eventually grey out the wood envelope, various depths were used ranging from 3" to 4.5" as well as a rotating arrangement of thickness' from 1" to 2" to preserve the visual interest. All of the individual scrap pieces alternate in multiples totaling 72 inches and were screwed from the side into the next piece over. Vertical end caps and trim pieces made from ripped heart pine barn wood provided a seal for the rest of the framing. The door of Shed 'A' featured a mosaic of various flooring scraps framed in old-growth pine slats.

Fence 'A' was decked with an overlapping pattern of 2x6 scraps two and four feet long (see Figure 18). A majority of these wood scraps were end cuts destined for the landfill. The alternating 2x6 were screwed into vertical and horizontal stringers on the backside of the fence wall. The top featured a 2x6 cap while the inside of the gate jamb is faced with a thick true dimensional 1x4 made from hardwood oak to which the gate is hung with T-hinges. The spaced picket style gate in contrast with the solid wood fence was made from pine flooring scraps salvaged from the Tanner Lumber Co. building on UGA's North Campus. The gate slats were screwed from the backside into an antique pine frame.

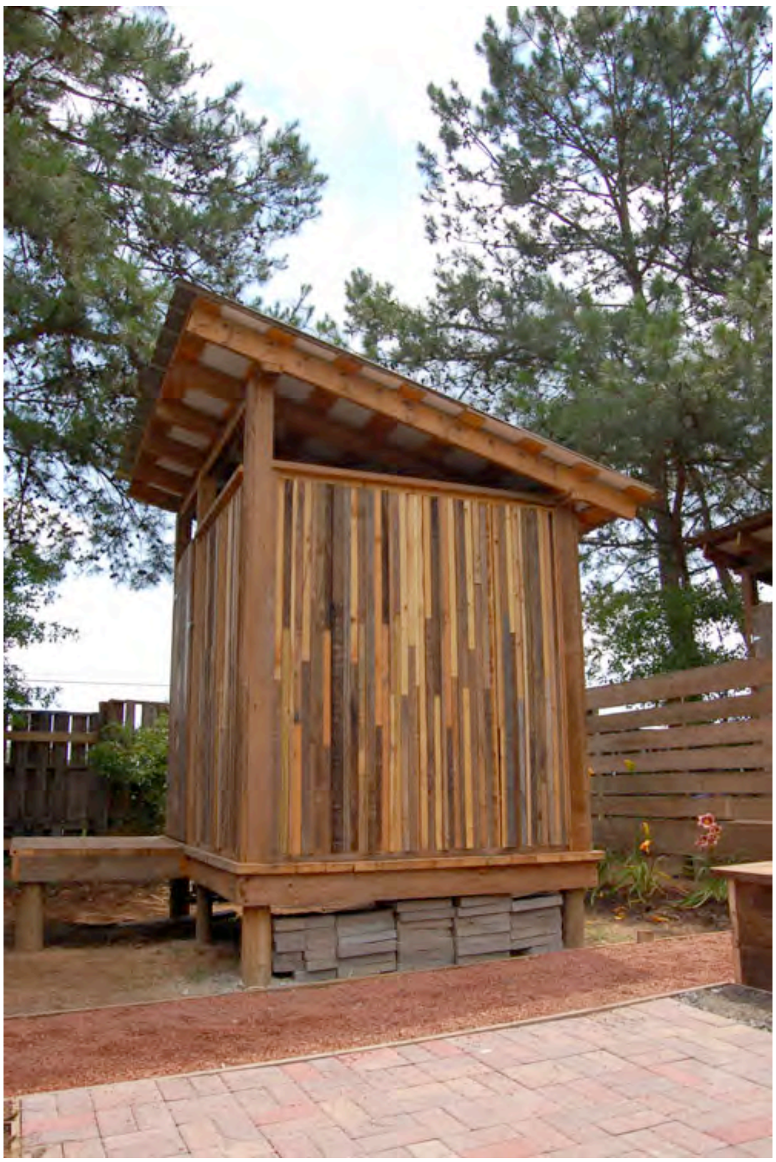

Figure 17: Tool Shed 'A' (source: Author 2012)

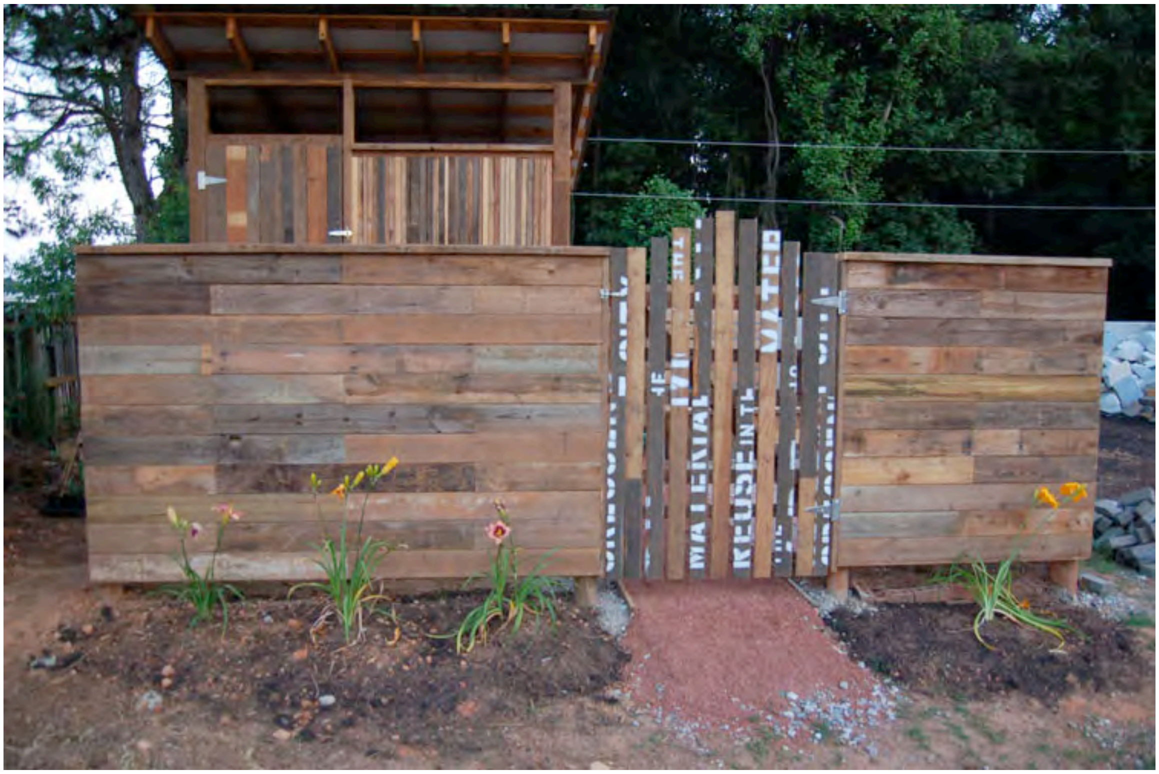

Figure 18: Fence with Gate 'A' (source: Author 2012)

The custom raised planter bed 'A' (see Figure 19) which intentionally frames one side of the patio was essentially the same construction as the solid wood fence using 2x6 scraps cut into staggered three and six foot sections. The scraps were tied to four interior corner posts made from antique true dimensional 2x4 scraps. The top, which doubles as seating, was made from 2x8 salvaged from a 1950's era barn with mitered forty-five degree corners. Although each structure is quite bulky and voluminous, the purpose of each structure was to capture lumber that was undeniably headed to a landfill or a burn pit. Each of the landscape items in Zone 'A' was built with significant structural integrity and eclectic style, while providing the function of utilizing wood scrap waste that represents a large part of the wood waste stream.

Figure 19: Raised Bed 'A' (source: Author 2012)

Zone 2: Full Length Dimensional Lumber

In comparison to Zone 1, the next zone was much more conservative and lightweight. Tool shed ‘B’ featured identical platform 2x4 stick framing with a cantilevered tin shed roof and naturally lit clerestory; however, in contrast, was clad in vertical hardwood hickory one-inch thick by eight, ten and twelve inch wide flat board salvaged from a 1950’s era pole barn (see Figure 20). Instead of plywood sheathing, the interior studwork has blocking for nailing the siding and 1x8 pine for diagonal bracing. The end caps and trim pieces found on tool shed ‘A’ were replicated on tool shed ‘B’ yet tool shed ‘B’ is nearly half the weight of tool shed ‘A.’ The door of tool shed ‘B’ was built of solid wood matching the solid wood siding.

Figure 20: Tool Shed 'B' (source: Author 2012)

Figure 21: Fence with Gate 'B' (source: Author 2012)

Figure 22: Raised Bed 'B' (source: Author 2012)

Fence 'B' in contrast to the solid wood siding of tool shed 'B' featured a more 'porous' ranch style fence with a horizontal arrangement of flat board slats (see Figure 21). Vertical stringers provided support for the hardwood slats but unlike fence 'A' this fence excluded the cap. The gate, matching the vertical siding of tool shed 'B' was constructed of solid wood aligned perfectly with the top of the fence. The corresponding raised bed 'B' was pine-framed in a rectangular shape with matching hickory slats (see Figure 22).

Zone 3: Pallets

The chosen wood waste material used in Zone 3 was the common hardwood pallet. Weighing in at one thousand pounds less than the first structure, tool shed 'C' featured an old growth pine timber frame with a shed tin roof and open-air clerestory (see Figure 23). The timber frame was needed in this structure because of its openness, which allowed for the interior cavities to be plugged with full palettes, whereas a stud framing system would have been redundant. Because a timber frame's abnormally large members cannot be screwed as tight as a 2x4 system, T-plates and L-brackets were used to anchor and bolt the structural members together. Though not technically a structural unit, the pallet walls form a cohesive and firm laterally stable unit encompassing the entire building. In terms of colors, the dark timber frame structure was starkly different yet in harmony with the light-colored oak pallet cladding. The door in contrast to the openness of the slatted pallet walls was solid wood, made from reused pallet slats attached to a pine frame.

Figure 23: Tool Shed 'C' (source: Author 2012)

Figure 24: Fence with Gate 'C' (source: Author 2012)

Fence ‘C’ identical to its tool shed counterpart, is also clad completely in oak and hickory pallets (see Figure 24). The top is capped like fence ‘A’ with a 2x6” and the interior jamb is also a hardwood true-dimensional 1x4 used to hang the gate hinges. The gate is fabricated with thin picketed six-foot long hickory and oak slats stripped from unusually large Hardie board siding pallets and framed as all the doors are with pine slats. Finally raised bed ‘C’ is composed of a heavy true-dimensional 2x4 frame plugged with smaller custom cut pallet sections (see Figure 25). The framing of this planter box is made of salvaged 2x4 that came from a house damaged in a fire giving the boards a blackened exterior appearance in direct opposition to the light hardwood pallets.

Figure 25: Raised Bed 'C' (source: Author 2012)

Non-Reused Materials

Although 98 percent of the material composition of the Reuse Village is reclaimed materials, some of the components simply must be virgin materials and purchased conventionally. The main component in this respect was hardware, particularly screws. An estimated ten pounds of screws were used in each zone, though slightly more in Zone ‘A’ than ‘B’ or ‘C’. In addition other metal hardware such as door latches, brackets and plates were used in various structures. Each platform and fence post utilized at least one and one half 80-pound bags of concrete for use in minimum eighteen-inch deep holes. Finally, each tool shed roof utilized Perma-felt, a synthetic geotextile weather barrier used to combat rain, especially helpful when using reclaimed tin roofing that has dozens of pre-existing holes. A similar geotextile liner was used in each raised bed as well, to limit soil contact with the wood frames in order to prolong the life of the timber.

Comparison: the 'Lowes' Model

Without a baseline comparison model, there was little evidence for this study to support the effectiveness of the reused product versus the conventional product. Three comparable items of similar dimensions and qualities were used in this survey and rated by study participants with the same five criteria as landscape items in zone 'A', 'B' and 'C.' The 'Lowes' tool shed chosen as a comparison model for this study was a seven foot by seven foot cedar shed with traditional horizontal beveled siding and cedar shake roof. The gable ended roof pitch was very low and façade featured a small window at front paired with a classic farmhouse Dutch door.

The 'Lowes' fence selected for comparison is an eight-foot wide by six-foot high dog-eared section decked with 5/8" thick pressure treated spruce slats. This prefabricated fence section with built-in 2x4 stringers is specifically designed for easy hanging on typical eight-foot spaced posts. Finally the 'Lowes' raised bed used for comparison has an identical construction application to raised bed 'A' except instead of pine 2x6, it is made from Western red cedar. The rationale for cedar is because in its untreated form it is an effective alternative to pressure treated lumber, as it is non-toxic and has natural resistance to decay, which is preferable for planter boxes that grow produce.

Figure 26: Tool Shed 'Lowes' (source: Cedar Shed Industries 2012)

Figure 27: Fence with Gate 'Lowes' (source: Lowe's 2012)

Figure 28: Bed 'Lowes' (source: Garden City Designs 2012)

Evaluation Data and Findings

Quantitative data gathered during the construction of the Reuse Village was generated to provide study participants with supplemental evidence to assist in their judgments as well as assist in the author's determination in the feasibility of reused materials in the landscape. The supplemental data sheet located in Table 5 (and Appendix C) was used as an overview of important factual data pertinent to the construction process and evaluation of constructed landscape items. The supplemental data sheet also provided survey participants with a clearer picture of the similarities and differences of the reused landscape items versus the conventional products.

Table 5: Supplemental Data Sheet (source: Author 2012)

Item	Weight	Hours/Cost	Source	EE	Dimensions	LF Envelope	LF Total	Wood Type	Wood Age
Shed 'A'	1768.1	20/$2400	<20	3	6x8'	996	1543	Pine/HW	Mix
Shed 'B'	1034.4	13/$1620	<20	1	6x8'	168	735	HW	50s
Shed 'C'	855.1	14/$1680	20-50	2	6x8'	170	480	HW	Mod
Shed 'Lowes'	770	8/$1899	500-2000	4	7x7'	n/a	n/a	W. Cedar	Mod
Fence 'A'	251.5	2/$120	<20	3	5x8'	96	151	Pine	Mix
Fence 'B'	126	1/$120	<20	2	5x8'	56	87	HW	50s
Fence 'C'	149.4	1/$90	<20	1	5x8'	60	148	HW	Mod
Fence 'Lowes'	140	1/$52	>500	4	6x8'	120	152	Pine PT	Mod
Gate 'A'	39.8	1.5/$90	<20	3	45"x6' H	66	101	Pine	Antique
Gate 'B'	41.6	1.5/$120	<20	2	46"x5' H	30	51	HW	50s
Gate 'C'	27.2	1.5/$75	<20	1	44"x5' H	60	81	HW	Mod
Bed 'A'	139.2	1/$120	<20	1	24x60"	64	72	Pine	Mix
Bed 'B'	137.6	1/$120	<20	3	36x60"	36	76	Pine	Mix
Bed 'C'	124	1/$120	<20	2	28x60"	88	150	Pine/HW	Ant/Mod
Bed 'Lowes'	95	1/$152	500-2000	4	24x60"	64	72	W. Cedar	Mod

Item	Landscape Item
Weight	Total Weight of Structure
Hours	Estimated Hours of Construction
Cost	Estimated Cost (Construction + Salvage + Materials)
Source	Origin of Wood in Miles
EE	Embodied Energy Ranking (1 = best performance or lowest embodied energy)
Dimensions	Square Foot Dimensions
LF Envelope	Total Linear Footage of Wood in Envelope
LF Total	Total Linear Footage of Wood in Structure
Wood Type	Species of Wood
Wood Age	Era of Wood

Weight

Reclaimed wood is generally much heavier than conventional or modern lumber found at home-improvement or hardware stores, primarily as a result of the density of first growth or second growth trees (Falk 2004). To verify this claim, each material used in this project was weighed individually on an agricultural scale and totaled. The weight of a structure is important in the practicality of a product especially with larger structures (such as the tool sheds), because the heavier it is, the harder it is to logistically handle. By far, the heaviest structure in this study was tool shed 'A' at nearly 1800 pounds. Tool shed 'B' with a much simpler cladding material (although hardwood) and application was almost half the weight of shed 'A' at a little over 1000 pounds. Surprisingly the timber-framed shed 'C' with oversized antique pine framing members weighed almost 1,000 pounds less than tool shed 'A' and just 80 pounds more than the conventional 'Lowes' tool shed. Despite the heaviness of hardwood pallets, the nine foot-long, century-old antique pine beams used in shed 'C' (salvaged from the sill of an old farmhouse in Madison County, Georgia) at closer inspection had significantly low *moisture content*[35] and subsequently less weight.

Similar to Shed 'A,' the wood scrap fence weighed considerably more than each of its counterparts at 251.5 pounds for the eight-foot section. Each of the other fences was relatively lightweight with the horizontally clad 'ranch-style' fence 'B' weighing the least followed by the pressure treated, dog-eared spruce 'Lowes' fence and hardwood pallet fence. Each of the reused raised beds, though fairly small in size, weighed more than 100 pounds each, with the exception of the cedar-framed 'Lowes' bed slightly less. In addition to the practicality of moving and transporting each item, weight also plays a significant role in embodied energy, which will be explained in the next few paragraphs.

Hours and Cost

Labor costs likely the have the gravest consequences for a reuse project if managed haphazardly, thus is why so much attention was paid to salvage and reuse hours worked and a prescribed hourly rate as described in Chapter 3. Equally, important and symbiotic with labor is a monetary value assigned to products or

[35] Moisture content (MC) is the amount of water contained in wood expressed as a percentage (Winterbottom 2000). At the point of sale, wood usually has a MC of 15 to 19 percent, but dries out to as low as 8 percent as time goes by; 12 percent MC is optimum for stability (Winterbottom 2000).

materials as a result. In order to streamline the survey, total hours for reuse (of the landscape item) and suggested retail price were displayed on the supplemental data sheet and denoted as “hours” and “cost” respectively. Although “hours” only reflected the total time spent on the reuse of the item in construction, the retail “cost” totaled the amount of hours in the procurement (salvage) and fabrication (reuse) of each item as well as the cost of materials.

As a result of the author’s background in construction management and particularly carpentry, the hours calculation were derived from the estimated time it would take to construct each item if all materials were processed and ready for fabrication (see Chapter 3). In addition, a baseline hourly rate common to the construction industry was used for the purposes of this study and this rate was also estimated according to the author’s personal experience in the field of construction. As mentioned in Chapter 3, different regions of the country have different pay scales for semi-skilled and skilled carpenters, but for the purposes of this study, the $20 and $40 per hour rate are appropriate to this region.

In contrast to an assembly line, the cutting of materials to various lengths was accounted for in the fabrication process, making some items much more time and labor intense than others. It is unquestionable that the relatively high retail cost of shed ‘A’ was related to the painstaking process of engineering the scrap wall envelope, factoring in the amount of hours it takes to accomplish this small feat. Considering that each wall section consisted of anywhere between 60 and 100 pieces of scrap, generally requiring one cut for each piece, this method required additional labor; substantially more than other landscape items in the study. The comparatively “stripped down” approaches of shed ‘B’ and shed ‘C’ called for a more reasonable price and fabrication time, even though each style was markedly different. In terms of simplicity of construction for the consumer, shed ‘B’ using hardwood slats on a traditional stick frame consisted of the most reasonable model, although the pallets used in shed ‘C’ are readily available in any market and require relatively small amounts of cutting in this study. In comparison it was estimated that the ‘Lowes’ tool shed, which is available as a kit, would require eight hours of fabrication by a skilled carpenter. The relative cost of this item; however, was disproportionately higher than the other reuse models.

The reused fence sections were less competitive in pricing in contrast to the standard ‘Lowes’ model; however, this might have as much to do with quality and material cost than labor. Fence ‘B’ for example, was constructed with hardwood flat board priced at $1 per linear foot, thus accounting for $56 alone in material costs. Since the ‘Lowes’ fence section was made pre-fabricated, labor costs were not reflected in the retail price of the $52 item, making it twice as competitive as two of the reused products. Fence ‘C’ made from pallets featured the lowest price of the reused items as a result of the minimal time it takes to procure the material. All of the reused raised beds were similarly easy in construction application and material cost in contrast to the ‘Lowes’ raised bed made from Western red cedar, which is precipitously more costly in raw materials as it is only found in the West Coast.

In summation, a significantly more complicated design often commands an equally high cost or retail price. Additionally products such as the ‘Lowes’ tool shed and raised bed, composed of products that require long distances of transport

(Western red cedar), also involve added material costs to offset shipping. In terms of market feasibility, the landscape items featuring scrap wood seem less likely to succeed compared to "stripped down" and uncomplicated models.

Source and Embodied Energy

The source of materials, as shown above, has a direct correlation with retail cost in products, but just as much it has importance in calculating the cost of energy or energy efficiency of materials and products. As previously mentioned, all of the reused items were harvested within twenty miles of the reuse site (indicated on the supplemental data sheet in Appendix C) with the exception of the beams used in the timber frame of Shed 'C' that were salvaged from an adjacent county (35 miles away). Although the actual source of materials with each 'Lowes' product was not always revealed by the retailer, an assumption based on material type and availability determined the approximate source; for example, it is known that Western red cedar (used in the Lowes Shed and Raised Bed), is primarily harvested in the American West and Canada, a distance of more than 2000 miles, while Spruce (used in the prefabricated Lowes fence) similarly is found well outside the Southern United States, primarily in higher elevation forests of New England and the West Coast.

Embodied energy, the amount of energy required to produce an object, was calculated using the factors of source as well as other data, specifically volume and electricity usage. Each landscape item was assigned a ranking (from 1 to 4) on the supplemental data sheet (see Appendix C) according to embodied energy calculations provided in Appendix D. For example, an item ranked 4th has the highest embodied energy or the lowest energy efficiency compared to an item ranked 1st with the lowest embodied energy or best energy efficiency.

In the case of the tool sheds, since all designs featured similar dimensions, a calculation was made using a comparison of one wall of each item. As suspected, the transport of Western red cedar cross-country by freight gave the 'Lowes' tool shed a significantly higher total embodied energy (679,206 Btus/100 LF), despite it having the smallest basic embodied energy (38,423 Btus/100 LF) as it is primarily concerned only with volume. The thick and bulky tool shed 'A' contained (by far) the highest basic embodied energy, as it was four times thicker and twice the weight of the other wall sections. Also adding to the total embodied energy of tool shed 'A' was the amount of energy usage of excessive chop saw cuts measured *at the plug*[36]. Tool shed 'C' created slightly more embodied energy as a result of its weight at 120 pounds compared to 93 pounds of tool shed 'B.'

The weight of Fence 'A' as well as its laborious construction method in cladding, made it the second-most energy costly in terms of embodied energy, whereas the transportation of the 'Lowes' spruce fence sections made it the least energy efficient. Despite the similarity in the weight of raised bed 'A' and 'B,' the difference in scraps coming from on-site compared to twenty miles in distance made bed 'B' more energy costly in comparison.

[36] Electricity measured at the outlet, instead of by a generator. Gas-powered generators use significant amounts of power due to transmission losses (Thompson and Sorvig 2008)

Additional Evaluation Considerations: WARM Model and Treatment

Another alternative to embodied energy calculations found is the EPA Waste Reduction Model (WARM). Although WARM was unable to accurately compare conventional and reused wood as products, it was able to provide the carbon dioxide impact of waste reduction and compare waste reuse or "reduction" it to various waste management alternatives (such as landfilling, combustion and recycling). However, if you assume that conventional products will eventually be 'waste' products as they are designed to be, the WARM model does indicate how much emissions savings are available through wood reuse comparatively. In total, all of the reused wood amounts to about 5,732 pounds or 2.86 tons of materials removed from the waste stream. This number was plugged into the WARM model to present the waste management strategic comparisons.

Results of the WARM model, featured in Appendix E provide data on two separate factors, Green House Gas emissions (GHG) measured in million tons of CO2 equivalent (MTCO2 E) and CO2 emissions measured in million of British Thermal Units (BTUs). With GHG emissions, a negative value was produced indicating an identical amount of savings (4 million BTUs) by source reduction or reuse of wood products compared to both combustion and landfilling. In contrast, the comparison of wood materials recycling and reuse showed that reuse created an increase of GHG emissions. Alternatively wood recycling compared to reuse in terms of CO2 emissions was significantly different as reuse produced a savings of 12 million BTUs, equivalent to two barrels of oil or 94 gallons of gasoline. The reasons for such a large emissions reduction was a result of wood recycling resulting in an increase of 2 million BTUs compared to a reduction of 10 million BTUs through wood reuse. Interestingly, landfilling wood products slightly reduced emissions by 1 million BTUs in comparison to recycling. Wood reuse on the other hand produced 13 million less BTUs of energy savings than combustion, equivalent to 101 gallons of gasoline. Although, both combustion and source reduction (reuse) provided overall emissions savings, combustion clearly was more useful in C02 reduction. Overall, the data shows that even on a small-scale reuse or source reduction of wood waste can provide significant savings of emissions. However, it is also clear that comparing large-scale modeling such as WARM with small-scale projects is quite difficult and confusing, as the EPA methodology requires someone with substantial scientific background to understand.

Another important factor in the evaluation of landscape products in this study is the weatherization and treatment of wood. Weather, in the context of time, has a profound impact on the quality and durability of wood often overlooked by designers. One major difference in the conventional landscape items versus the reused landscape items is that modern exterior products are almost always chemically treated or naturally weather-resistant material to counter weatherization and rot (such as cedar or cypress). The treated lumber used in the 'Lowes' fence section, for example, will ultimately prolong the life of an otherwise vulnerable material.

Conversely, the treatment of lumber also has significant negative environmental consequences, although the industry has improved greatly from turn-of-the-century days when creosote and '*penta*'[37] were widely used, and more recently as a result of substantial reform and partial ban in the use of chromated copper arsenic (CCA) perservative. Nonetheless, treated lumber is a large part of the overall market accounting for 20 percent of total softwood production but it also presents a serious ecological problem in its disposal (Thompson and Sorvig 2008). As a result of the detrimental impacts such treatments have on humans and nature, most of the lumber used in the Reuse Village was not treated with toxic wood preservatives. Unfortunately, because of this, there will be some negative effects on quality, durability and subsequent life of reused landscape products. Avoiding ground contact, such as having tool sheds raised on piers or using geotextile lining inside raised beds will likely improve the viability of the products.

There are two observations regarding the weatherization of reused wood compared to treatment of conventional 'Lowes' products realized in this project. First is that the reused lumber is older-growth, more dense and has the propensity to last much longer than similarly untreated conventional lumber though this is not definitively known. Second, is that it seems the environmental benefits of avoiding treatment far outweighs any loss of durability and efficiency in using non-treated reclaimed wood. Some of the durability issues were addressed by the choice of material type and application during construction (such as avoiding water pooling or ground contact), but in some cases, weather (such as UV and water exposure) is unavoidable. In conclusion, weather is an important aspect in the life of a material, but

[37] Pentachlorophenol is a wood preservative used to treat lumber in the 1930's known by the EPA as a "probable human carcinogen." Similar to creosote, penta is not available for public use, but is still used to treat power poles and railroad ties.

it was decided that the environmental costs of treatment are far too great and potentially unnecessary as reclaimed wood products are durable in their age and density. The results discussed in the next chapter will augment the previous determinations made in this chapter as well as the interpretation of current literature on theoretical frameworks and practicality discussed in chapter two in order to come up with a reasonable conclusion of the overarching question in the final chapter.

CHAPTER FIVE:

SURVEY FINDINGS

Interpreting Data

The survey findings explained in this chapter, and available in Appendix B, represent one of the chosen methods for analyzing data in this study for comparison of the reuse versus conventional product. The survey findings provide a glimpse into the minds of professionals that routinely have to specify materials and products to service their clients and keep construction projects moving efficiently. There is no doubt that the current in the field of landscape architecture and contracting has changed substantially to reflect the growing influence of the green building movement on the values of designers and builders. Interpreting the professional opinions of landscape and construction professionals in conjunction with the experiential results recorded and discussed in the previous Chapter 4 as well as the analysis of the current body of literature will hopefully culminate in a clearer picture of how effective reuse or feasible reused lumber is as a building material in landscape design and construction. First, the results will be discussed in comparison of individual product performance according to criteria that will reveal which products were successful and which products failed to garner support. Next, a particular analysis will be focused on how well products competed as 'zones' or according to wood waste type in contrast with the conventional models. An overview of the complete results represented as mean scores between 1 and 5 shows both categorical and zonal performance (see Table 6).

Table 6: Survey Results (source: McDowell 2012)

item	criteria 1	criteria 2	criteria 3	criteria 4	criteria 5	total
shed	**aesthetics**	**affordability**	**durability**	**efficiency**	**ecological impact**	**category**
A	4.33	3.00	4.17	3.83	4.17	3.90
B	4.33	3.83	4.33	4.50	4.50	4.30
C	2.33	4.17	3.67	4.50	4.17	3.77
L	2.67	3.67	3.67	2.00	1.50	2.70
fence/gate						
A	4.33	3.67	3.33	4.67	4.33	4.07
B	4.00	3.00	3.50	4.50	4.33	3.87
C	2.33	3.50	3.00	4.83	4.67	3.67
L	2.50	4.17	3.33	2.00	1.50	2.70
bed						
A	4.67	4.50	2.83	4.67	4.50	4.23
B	4.33	4.50	3.33	4.50	4.33	4.20
C	2.83	4.17	2.83	4.50	4.33	3.73
L	3.33	3.00	3.00	1.83	1.50	2.53
zone						
A	4.44	3.72	3.44	4.39	4.33	4.07
B	4.22	3.78	3.72	4.50	4.39	4.12
C	2.50	3.94	3.17	4.61	4.39	3.72
L	2.83	3.61	3.33	1.94	1.50	2.64

Yellow = Highest Score
Grey= Lowest Score

Results by Item

Tool Shed

In the aesthetics category, the disparity of scores from top to bottom in the tool shed were particularly pronounced as both tool shed 'A' and 'B' tied with scores of 4.33 while shed 'C' and shed 'Lowes' rounded out the bottom half with 2.33 and 2.67 respectively. In affordability, shed 'C' earned the highest mark at an average of 4.17, followed closely by 'B' and 'Lowes.' Tool shed 'A' scored the lowest mean at 3.0.

Similar to aesthetics, shed 'C' and 'Lowes' ranked far lower (equally with a marginal 3.67) than 'A' and 'B' in durability. In both efficiency and ecological impact categories the 'Lowes' model scored abysmally low (2.0 in efficiency and 1.5 in ecological impact) compared to the reused wood products (all above 3.83). Both shed 'B' and 'C' were viewed as the most favorable in efficiency and ecological impact though 'A' was close behind.

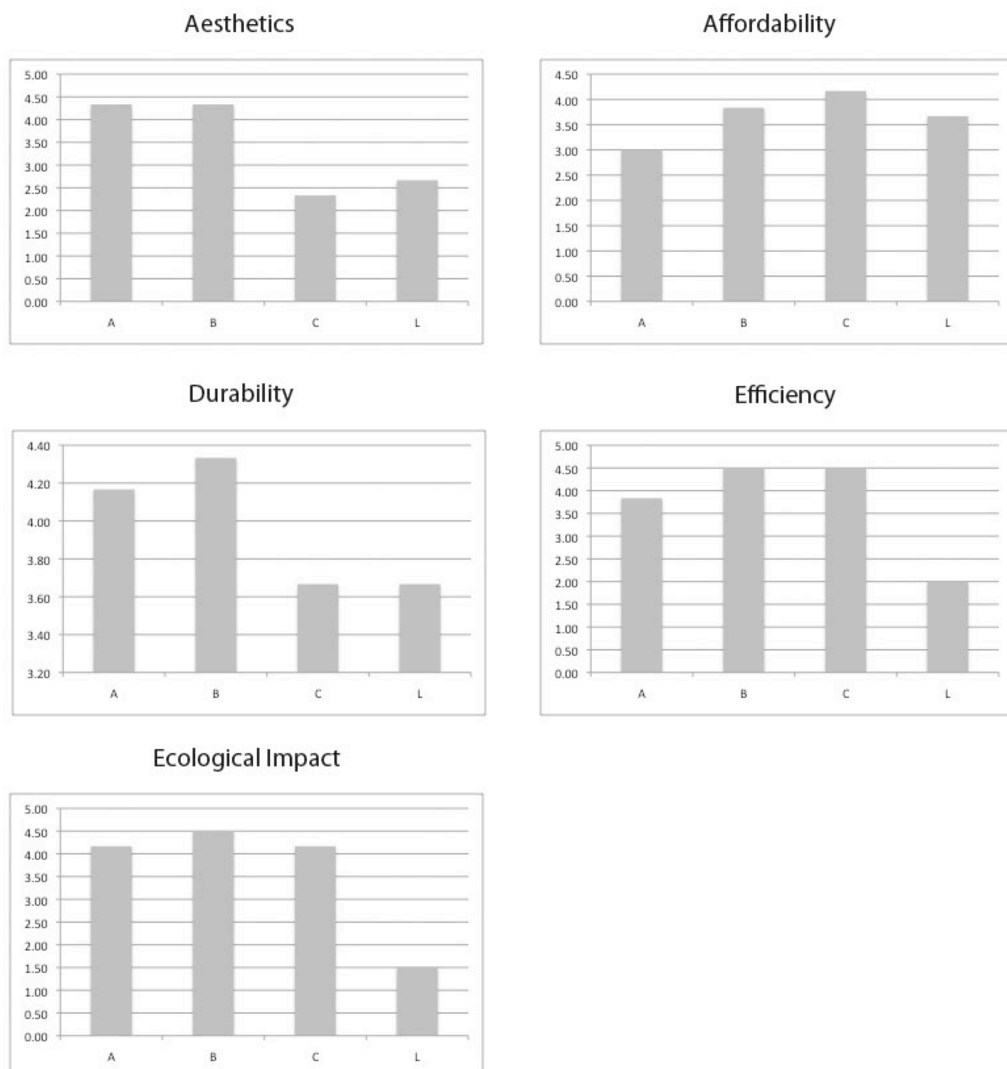

Figure 29: Tool Shed Comparison by Category (source: Author 2012)

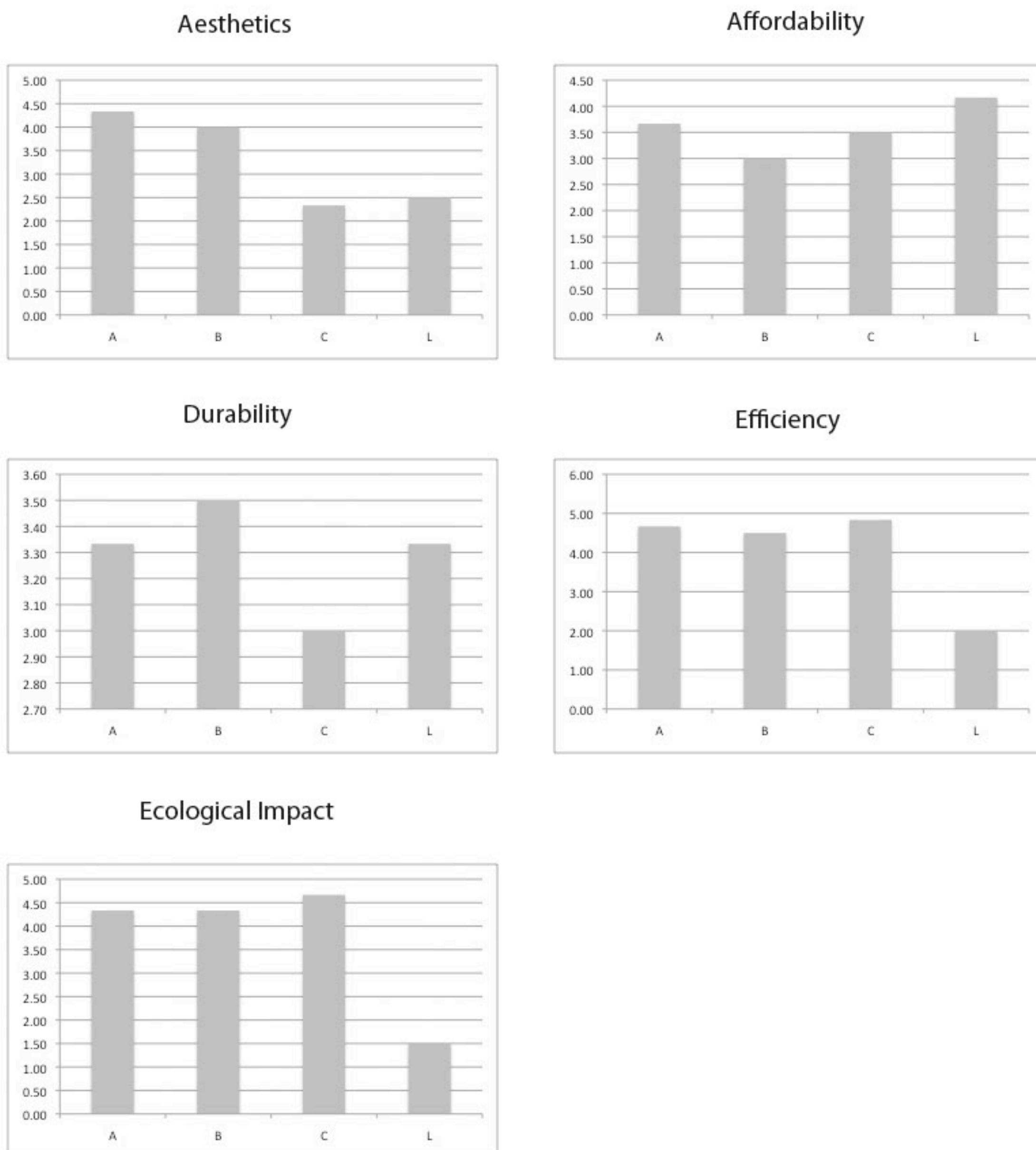

Figure 30: Fence with Gate Comparison by Category (source: Author 2012)

Fence with Gate

Aesthetically, fence with gate 'A' was ranked the highest at 4.33, followed by 'B' at an even 4.0. Fence with gate 'C' scored the lowest at 2.33 not far behind fence with gate 'Lowes' at 2.5. In the affordability category, fence with gate 'Lowes' earned the highest mean score at 4.17, whereas fence with gate 'B' received the lowest score at 3.0 and 'A' and 'C' scored in between at 3.67 and 3.5 respectively. Although overall scores in durability were lower than in other categories, again disparity was low among items. Fence with gate 'B' scored highest at 3.5 while 'C' scored the lowest at 3.0, with 'A' and 'Lowes' tied at 3.33. In efficiency, fence with gate 'C' received the highest mean score by category and in the entire study with a 4.83. Fence with gate 'Lowes' scored the lowest mean at 2.0. In ecological impact, fence with gate 'C' earned the highest mean score of 4.67, followed closely by fence with gate 'A' and 'B' equally receiving a 4.33 rating. Again fence with gate 'Lowes' scored by far the lowest at 1.50.

Raised Bed

Aesthetically, raised bed 'A' scored highest marks at 4.67 and 'B' not far behind at 4.33 with 'C' being the lowest at 2.83. Raised bed 'Lowes' scored marginally in the aesthetics category at 3.33. In affordability, raised bed 'A' and 'B' equally scored the highest mean at 4.5 while raised bed 'Lowes' received the lowest score at 3.0. The disparity in affordability scores was much lower than aesthetics so either opinion of retail prices was seen as equally affordable or unaffordable. All items scored marginal in terms of durability with raised bed 'A' and 'C' tying for the lowest score at 2.83 while bed 'B' earned the highest at 3.33 followed by bed 'Lowes' at 3.0. In efficiency and ecological impact, a large disparity between the reused items and conventional 'Lowes' item emerged, whereas in aesthetics items 'C' and 'Lowes' were polarized from 'A' and 'B' by low scores. With efficiency raised bed 'A' scored a 4.67 as the highest mean followed by bed 'B' and 'C' at 4.5, while raised bed 'Lowes' received a dramatically lower 1.83. In ecological impact, raised bed 'B' and 'C' each received the highest mean score of 4.39 with bed 'A' barely behind at 4.33.

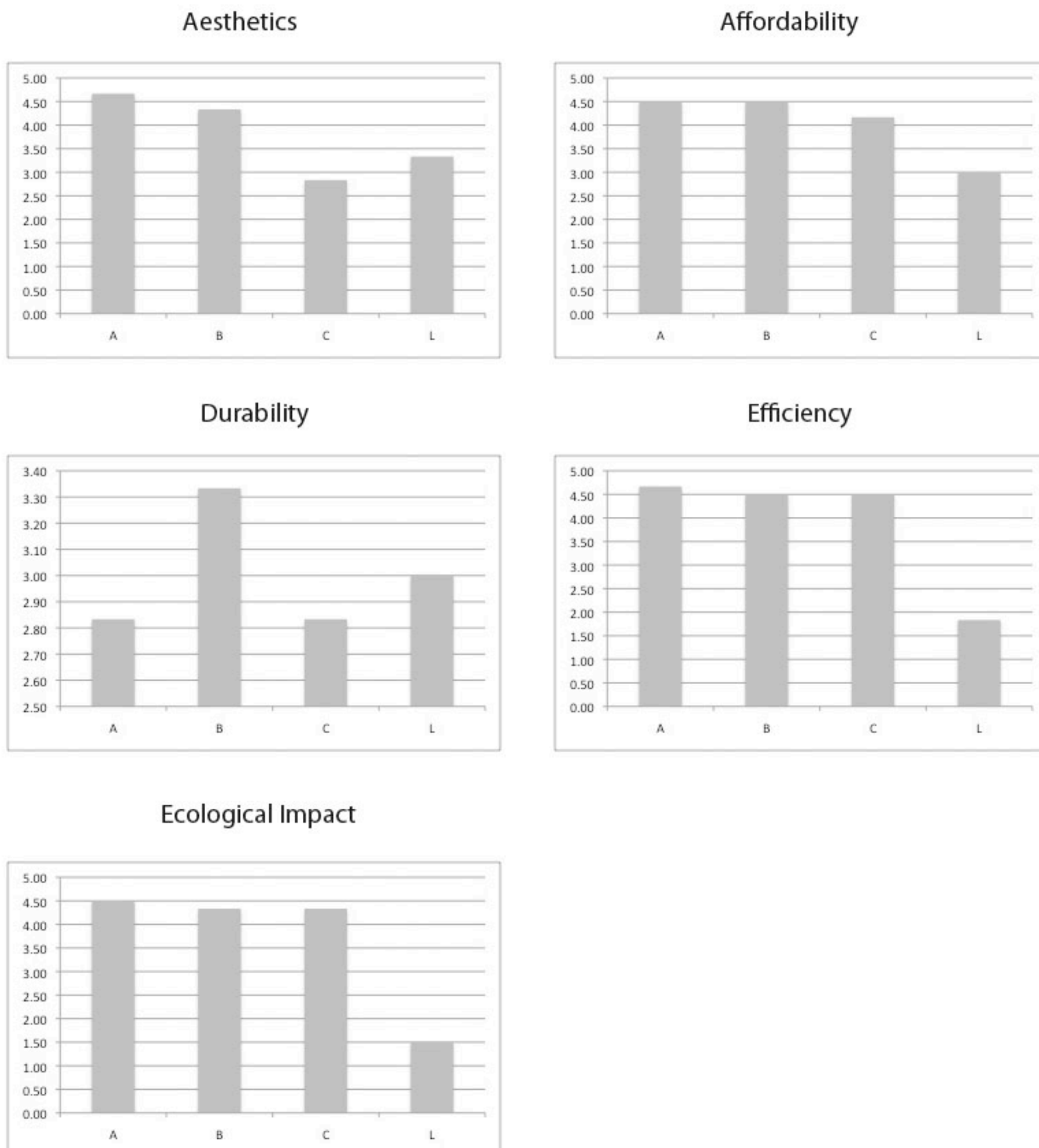

Figure 31: Raised Bed Comparison by Category (source: Author 2012)

Total by Category

Tool shed 'B' received the highest mean score of 4.30 of all categories, while shed 'Lowes' averaged the lowest overall mean at 2.7. Fence with gate 'A' earned the highest mean score average of 4.07 in each category, while fence with gate 'Lowes' received the lowest mean score average in each category at 2.7. Raised bed 'A' garnered the highest mean score in all categories of 4.23, and raised bed 'Lowes' scored the lowest at 2.53. Landscape items made from wood scraps and barn lumber (A and B) were the most consistent in overall performance by category while the 'Lowes' items were clearly the worst performers across the board.

Results by Zone

Aesthetics

Zone 'A' scored the highest mean rating of 4.44, while zone 'C' rounded out the lowest rating at 2.5. Clearly the landscape items in Zone 'A' composed of wood scraps, though somewhat eccentric, were the aesthetic favorite followed by the more conservative or traditional items in 'B.' Landscape items made from wooden pallets in Zone 'C' were widely disapproved in aesthetic quality followed closely by the 'Lowes' items, which received particularly low marks in looks.

Affordability

Zone 'C' of wooden pallet structures scored the highest mean rating of 3.94, narrowly beating both 'B' dimensional lumber items at 3.78 and 'A' wood scrap items at 3.72. The lowest rating at 3.61 was zone 'Lowes.' The pallet landscape items in zone 'C' rebounded in terms of affordability, though by a small margin. Generally all zones were seen as having moderate affordability.

Durability

Zone 'B' composed of barn lumber received the highest mean rating of 3.72, as zone 'C' with pallet structures received the lowest rating with 3.17. In terms of durability the more conservative items made from hardwood barn lumber received the most praise, with the Lowes items not far behind. The pallet structures received the lowest ranking probably as a result of material application and exposure of pallet structures.

Efficiency

Zone 'C' earned the highest mean rating of 4.61, while zone 'Lowes' scored the lowest at 2.94. The pallet structures got high marks likely because of the relatively easy construction application and method of procuring pallet materials versus the higher embodied energy and transport of non-native cedar and spruce from Lowe's products.

Ecological Impact

Zone 'C' and 'B' equally scored the highest mean rating of 4.39, as zone 'Lowes' scored the lowest rating at 1.6. Similar to the efficiency category pallets trumped Lowes products in being a local and available source with low transportation and production costs.

Overall Performance

In terms of overall performance, zone 'B' received the highest rating of 4.12 narrowly beating out zone 'A' at 4.07. The lowest rated zone by far was 'Lowes' at 2.64 while zone 'C' earned a marginal 3.72 overall. Both landscape items 'A' and 'B' performed well, the difference being that 'B' performed the best in all categories with its tool shed. Surprisingly by zone, 'B' only earned the highest rating in durability, but scored high enough in efficiency, ecological impact and aesthetics to hang on to the highest total ranking score.

Analysis

Aesthetically the landscape items made from wood scraps were the most attractive to reviewers while pallet structures being less uniform and "choppy"[38] were unable to escape the fact that they still look like pallets. In spite of this, the pallet structures were seen as being the most environmentally beneficial and efficient alternative to conventional products, which scored dismally. The Lowes products only succeeded in terms of affordability but didn't officially lead any category as durability proved mostly inconsequential. One potential reason for Lowes products' performing marginally in affordability was because cedar used in the raised bed comparison is markedly more expensive than standard conventional lumber, yet cedar was chosen in an attempt to avoid pressure treated lumber in bed construction. A general consensus that pressure treated and weather resistant lumber such as cedar is an

[38] "Choppy" was a note written on the survey of Landscape Faculty I

important consideration for wood in the landscape was indicative in better performance of the Lowes products in durability. The most consistent of landscape items happened to be the 'B' models, which scored the highest average overall. The relatively simple construction process, durability of hardwood and more traditional design aesthetic contributed to the success of the 'B' landscape items. Similarly, the pallet structures in the 'C' models performed well across the board despite its aesthetic laggings. In totality, the reused products reviewed in this study performed well against the conventional product, but it is yet to be known whether this was solely a result of the environmental leanings of design professionals. Nonetheless, the reuse structures embody the same potential as identified in Chapter 2 and Chapter 4.

In totality, all of the reused items were fairly successful in most categories, but as a result of the process many lessons of style and application could be taken from the experience. Despite the aesthetic success of shed 'A' the amount of labor involved would likely make it unrealistic for most situations. On one hand the scrap wood structures utilize a good amount of waste, but on the other hand the products create redundancy and require an inordinate amount of energy and labor. In contrast, the aesthetic failures of the pallet structures question the viability of it as a realistic building material as well. Pallets are extremely common, but are not applicable to every situation, thus they have probably a limited impact. The pallet structure could have been clad further on the inside to provide more protection from the elements, but the addition of time and labor to make this happen would counteract the greatest benefits of using pallets as is.

The middle of the road ‘B’ products have many positive qualities in terms of reduced labor and application costs; however, they could also be seen as having less character as the other structures. Regardless, in terms of competing against conventional Lowes products, the ‘B’ products would likely be the best candidate for performance and feasibility as a sustainable alternative. The reduced cost of materials and labor due to its application make it most affordable and efficient, thus making it more available to the public. Its traditional and populist aesthetic approach in the same light makes it more attractive to the masses and thus more marketable to a wide audience. One of the central themes in this project is making reclaimed wood a more mainstream product. In order to attain this goal, a straightforward mainstream approach to construction is key. The ‘B’ products are the best fit for establishing this result.

CHAPTER SIX:

CONCLUSIONS

The underlying justification for the Reuse Village experiment and this thesis was to gain knowledge into the effectiveness of reclaimed wood as a building product and design tool, specifically through the experiential building process followed up with a carefully orchestrated review by professionals within the design and construction industry. In addition, the fundamental framework for this study was to carry out the construction and review in conjunction with a comprehensive review of the existing body of academic and technical work in the fields of wood reuse, landscape construction and green building. While the experiential process represents a personal journey for the emerging designer, the professional design opinions and existing body of knowledge demonstrate a consensus among leaders in the industry. The ability for humans to engage and share ideas creates consensus that ultimately defines our culture and how we choose to design the world.

Building on Existing Research

In response to mounting global problems such as waste accumulation, designers from various disciplines have slowly initiated unity in the green building movement. Based in the notion that nature is a valuable model for human industrial systems, the emerging field of materials reuse as well as its green building counterparts in construction and industrial ecology, are focused on reversing the long-established "cradle-to-grave" mentality currently embraced by the US construction industry and instead utilize a closed loop systems approach inspired by the natural environment.

Materials reuse, and in the case of this study, wood reuse is one potential activity that can make a substantial impact in landscape design and construction. Salvaged wood, like wood in general, has an extremely low embodied energy in contrast to other materials that require invasive extraction from Earth, produce large amounts of CO2 during production and are non-renewable. Just as the timber resources of the US are vast, so to are the opportunities for wood waste salvage. Expansion of the green building industry has resulted in a dramatic increase in demand for reclaimed wood in landscape design and construction projects.

At the same time that the green building industry has begun to flourish, offering designers various material reuse credits through LEED and SITES, waste tipping fees, which have historically always been low, have begun to rise as a result of increased regulations and lack of landfill space making it more costly to generate large amounts of waste (Knecht 2010). More than anything reclaimed wood has greatest potential to relate a site to its cultural history. As Meg Calkins explains, the most compelling reason for using salvaged materials in the landscape "is the rich layer of meaning added to a place that may be difficult to achieve with new materials" (Calkins 2002). Incentivizing designers and contractors to use reclaimed materials as opposed to new, virgin materials is still a challenge despite potential energy savings and green building credits (Addis 2006).

Numerous questions surrounding wood reuse remain despite its many merits. Labor costs, availability of materials, quality control problems and lack of coordination within the supply chain are serious issues that prevent wood reuse from being implemented regularly in the field of landscape design and construction. Finding resolution to these impediments is key in the research and development as well as ultimate success of wood reuse in landscape design and construction.

Key Components to Reusing Wood in the Landscape

The built project of the Reuse Village not only provides tangible results for evaluation and synthesis of ideas but also reveals the errors and rewards of the decision-making process along the way, while the existing data provides the framework for focusing efforts and data collection. The survey results help to verify or refute the success of reused materials compared to conventional products. The following is a list of important lessons learned and conclusions determined as a result of the literature review of existing work, the implementation of the built project and the subsequent product review that tell us how feasible reused wood is as a building material in landscape design and construction:

1. *Reused wood has the aesthetic potential to compete with or improve upon conventional lumber products.* As evidenced in the success of tool shed 'A,' fence with gate 'A,' raised bed 'A' and tool shed 'B' reclaimed wood products performed well against comparison conventional landscape items. Uniformity is one key to aesthetics that plagued the pallet-based products. Reclaimed

wood has great potential to provide both eccentric and 'stripped down' traditional styles as seen in the popularity of both 'A' and 'B' products. The numerous sizes, types and colors of reclaimed wood also allows for the creative use and artful application of materials, whereas conventional materials are less useful. As a result of the many looks of reclaimed wood the designer can often let the materials inform the design process instead of designing solely based around function (Calkins 2002).

2. Reused wood has cultural and historical values specific to its local origin that can increase the appeal of a project whereas conventional lumber has little or no potential to add cultural and historical value on its own. In addition to its aesthetic qualities, reusing wood on landscape design and construction projects has the potential to relate a site to its history as well as provide much needed cultural values to a project through the use of local or on-site materials. In fact, in the Reuse Village, a significant percentage of the platforms and framing were constructed from a building harvested on site. Each piece of lumber applied to the landscape contains a "multitude of stories" as landscape architect, Marcia McNally explains (Calkins 2002). Although stories might not be readily apparent to a visitor; nail holes, writing, spray paint, tree rings, stamps, burn marks, saw marks, old hardware and other indications of the products former use are all examples of characteristics found in the lumber used in the Reuse Village. Locating materials early in the process, evaluating potential structures on site for material harvesting can are all potential strategies that can be employed to provide embedded cultural significance to a project through wood reuse (Calkins 2009).

3. Reused wood has the potential for far greater energy reduction benefits compared to conventional products, particularly with regards to embodied energy but is dependant on its source. The origin of reclaimed wood plays a huge role in its energy efficiency as a product. As demonstrated in the embodied energy calculations (see Appendix D) transportation of materials long-distance has tremendous energy implications for conventional products. Western red cedar, used in some of the comparison products, undoubtedly comes from somewhere in the West Coast, more than 2,000 miles from Athens. Shipping this material by truck or train expends tens of thousands of BTUs per unit. The local nature of reused building materials is a huge factor for the effectiveness of reclaimed wood in energy savings. However, buying reclaimed wood from another market is not as ecologically responsible. Thus, the availability of materials has a significant role in whether a project is efficient, both in cost and energy. As embodied energy looks at the entire production process, wood in general, beats out other materials because it doesn't require extraction from the Earth and it is a renewable resource. In addition to production and transport, the energy used in the fabrication of items is also a key factor. The primary drawbacks of embodied energy are that unlike life cycle assessment (LCA) it does not look at the long-term costs of maintenance and operation.

4. Reused wood has likely limitations in durability in comparison to conventional lumber products. Time is a major element of this project that was unable to be calculated. Durability is a primary component in the factors that time has on landscape items. Weather plays a huge role in the durability of wood in exterior situations, as well as its treatment. Much of the exterior grade lumber produced in the US is pressure treated; however, there are many ecological reasons why not to use treated lumber in the landscape. Naturally weather and rot-resistant woods such as cedar or cypress are alternatives to toxic pressure treated lumber, although their durability is likely overstated in its contemporary quality as lumber products across the board have continually declined as a result of overharvesting (Falk 2004). Not surprisingly, reclaimed lumber harvested from slow-growth forests has an unmatched density that provides it with similar weather and rot-resistant qualities. According to the Reuse Village surveys, protecting wood is an important value for design and construction professionals although wood in general is perceived as having durability issues compared with steel or concrete. Raised bed 'A' and 'C' both received low marks for durability concerns likely as a result of high incidence of ground contact. Pallet fence 'C' equally scored low as a result of the many horizontal braces that could potentially catch water. Reducing ground contact, using non-toxic or low-toxic preservatives and minimizing pooling areas are all strategies that can be employed by the design to assist in prolonging the life of wood in the landscape. Conventional pressure-treated lumber, whether toxic or not, is a trusted building product comparatively.

5. Reused wood is effective aesthetically but is particularly dependant on the material application and type as well as location. The use of pallets in the Reuse Village, though seen as being superior in energy efficiency, was the biggest failure in terms of aesthetics. The pallet structures, could potentially be more fitting in a rural environment and seen as non-conforming in an urban setting. Nonetheless, the pallets lack of uniformity as a result of the application led to its downfall. Instead, the contrasting material applications of the wood scrap and full dimensional lumber items were highly praised by participants. The reason for this is two fold: the scrap structures were playful, creative and thus attractive, whereas the full length dimensional lumber based structures were conservative, traditional and conforming making them available to a wider audience. Tool shed 'B' for example, would likely be the best fit for meeting historic commission requirements and not angering or serving as a point of contention for the neighborhood. Tool shed 'A' might inspire some but annoy others.

6. Reused wood has the potential for cost-efficiency, but is highly variable and conditional as a result of labor considerations as well as material availability. Reusing lumber in design and construction is labor intense because it not only requires ingenuity in construction because of varying sizes and qualities of timber, but also because it requires the salvage process. As a result, the prices of the materials or products are driven up higher than conventional products in many cases. The labor cost in shed 'A' compared to the 'Lowes' shed was significantly different because shed 'A' required more than twice the hours in labor (at $40 per hour) in addition to cost of salvage, the availability and transport of materials is primary determinant of cost-efficiency. If materials are not readily available, transport from an adjacent community is possibly needed, and transportation of bulky construction materials is especially burdensome to cost. Areas with sizable salvage markets are more likely to have an array of pricing options, which also aids the design specification process in terms of aesthetic considerations. As the salvage markets across the US slowly expand, salvaged lumber stands to benefit greatly compared to the conventional lumber industry, which is highly dependant on moving materials long distances along the supply chain. Where it lacks in aesthetics pallets certain benefits in energy efficiency, that is if they are used as-is. At closer inspection, one significant design specification with regards to the pallet landscape items is that minimal cutting is employed in their fabrication. The pallet is also highly available as a waste product and as a result is usually free. Using materials with the least amount of preparation or alteration is key in the energy and cost-efficiency of reclaimed wood products in the landscape.

7. Reused wood is generally regarded as being a more ecologically responsible and efficient building material compared to conventional lumber. As previous evidence indicates, as long as it is harvested locally, there is little wrong that reclaimed lumber can do. Reused lumber shares the positive attributes that make conventional lumber so effective such as renewability and low embodied energy with the added benefits of reducing the waste stream and significantly reducing production emissions attributed to the bloated construction industry and built environment "responsible for 40 percent of total materials extraction and 30 percent of energy consumption" in the US (Kibert, Sendzimir and Guy 2001, 3). Reusing lumber also has a number of direct and indirect effects that actually benefit the conventional timber industry such as reducing the strain on current forests and subsequently improving the current stand of timber. Durability and the effect of time is the only major downside to the efficiency of reclaimed lumber, but the older-growth lumber likely is just as durable as modern treated lumber. According to LCA findings, wood scores low compared to metal as a result of the operational and maintenance costs of replacing wood; however, landscape structures are quite different than buildings in terms of emissions attributed to operational functions and thus have dissimilar implications to the environment.

8. Reused wood has particular issues with quality control such as attaining a grade stamp, but this is not always a factor with landscape application. All lumber used in structural applications require a grade stamp from an ASLC accredited third-party grading entity. With the exception of bridges, decks and large outbuildings, local building codes do not enforce the grade stamp rule on landscape structures. If a building is considered 'habitable' it requires a grade stamp, but the tool sheds in the Reuse Village were below the square footage requirement for Athens, GA. Reclaimed lumber is particularly challenging in terms of quality control as it does not meet current building standards and requires re-grading to be used in structural situations. In this case, reclaimed lumber would not be economically feasible as it is extremely cost-prohibitive to have lumber individually inspected or re-graded. Using reclaimed lumber in landscape application mostly avoids these circumstances. New methods and technology for re-grading reclaimed lumber is currently being researched at the Forest Products Laboratory (FPL) and recent studies indicate flaws in the modern system of grading. Recent studies show that a majority (or 36 percent) of grade reduction occurred as a result of nail holes while an additional 26 percent was attributed to edge damage (Falk 1999). According to this rationale, merely cutting off the ends of salvaged lumber could significantly increase grade characteristics.

9 Reused wood is laborious, but streamlining of construction techniques could reduce the negative impacts of labor. Coming up with an easy, straightforward design is key to using reclaimed wood in landscape construction. Energy and labor intensive application such as the style used in tool shed 'A' is indicative of a complicated and somewhat costly design. Whereas, shed 'B' is virtually the opposite, utilizing a simple and labor efficient approach. Avoiding redundancy in material application is important in an efficient design.

10. Reused wood can be a practical alternative to conventional lumber in terms of performance and applicability. Reused lumber is not appropriate for every situation, but in many cases it is an effective alternative to conventional lumber as it can be environmentally, economically and culturally beneficial to a landscape design and construction project. The survey results of the Reuse Village demonstrate that conventional products are not necessarily the most effective design tools, at least from a designer's standpoint. Resolving issues of labor and associated costs, addressing durability, improving availability of the product and employing a straightforward design approach is key to the success of a reuse project.

Figure 29: Reclaimed Wood in the Landscape (source: Calkins 2000)

Opportunities for the Future: Closing the Loop

At present, it seems that reuse is severely handicapped by an overwhelming number of built-in and well-established forces, but in all actuality the tides have begun to slowly turn. The recent introduction and general acceptance of green building practices and standards has opened the floodgates of research and development investments creating a more inviting climate for reform and change. The feasibility and effectiveness of reusing wood in landscape construction and design is directly tied to the green building effort but also has the ability to function as its own industry. *The most important aspect of closing the loop of building materials and consequently utilizing reclaimed wood as an effective landscape design and construction material is creating an environment conducive to its success.*

There are six main principles that can be used to develop opportunities for wood reuse to better coordinate with landscape construction and design through continued reform of the design and construction industry, which are as follows:

I. Encourage existing and future wood waste reuse and recycling businesses or initiatives locally and regionally through efforts such as collaboration, information sharing, networking, transparency, recognition by the business community and regulatory community, and inclusion into legislation to create more availability for sourcing reclaimed wood and other materials.

II. Educate and train professionals and the general public on the benefits of wood reuse through workshops, presentations, demonstration projects, safety and regulatory training and introduction into high school and collegiate educational design curriculum to cultivate a better understanding of how to use and incorporate reclaimed wood in the landscape safely and effectively.

III. Emphasize the selling (strong) points of wood reuse such as aesthetic, economic and ecological impacts to clients because they ultimately determine the direction of a project.

IV. Coordinate better with all actors in the design and construction process from the supplier to the designer, contractor and client to facilitate smooth transitions throughout the design and construction process.

V. Become an expert on utilizing reclaimed wood as a sustainable building material and be aware of the risks in order to increase efficiency, add value and avoid potential drawbacks.

VI. Use reclaimed wood as a tool to inform and compliment the functional and creative aspects of the design process.

Future Research

There are many potential areas for future research that will undoubtedly assist in the development of wood reuse in the landscape. The Forest Product Laboratory (FPL) in Madison, Wisconsin, run by the USDA Forest Service is actively conducting research into wood reuse and its practical implications in the waste and construction industries (Falk 2002). Although wood and materials reuse is a fairly obscure topic, a handful of notable experts on the subject such as Bob Falk, Charles Kibert, Bradley Guy and Meg Calkins have written countless books, journal articles, academic papers and magazine articles examining the issues and potential benefits of reclaimed materials as an important construction material.

Exploring how better to alleviate complex issues (on a small scale) brought up in this study such as re-grading, cost efficiency, limited availability in the market, liability and safety issues and inclusion into the design and construction industry will ultimately lead to other academic research and are critical to the expansion of the larger industry. Investigating potential solutions such as increased regulatory and legislative presence in the materials reuse projects, use of reclaimed wood in community-based projects, cost-efficient strategies to reuse and project management with reclaimed wood are equally important in the development of reuse as an effective design tool for landscape designers and construction professionals.

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APPENDIX A:

STUDY SURVEY (SAMPLE)

Reuse Construction Survey

Instructions: Rank each landscape item listed at the left according to corresponding design criteria on a scale from 1-5, 1 meaning that the particular item being assessed is least effective and 5 meaning that the item being assessed is most effective .

Item	Criteria	1	2	3	4	5
Tool Shed 'A'	Aesthetics [Is the design marketable?]					
	Affordability [Is pricing competitive?]					
	Durability [Will the materials last?]					
	Efficiency [Is waste use maximized?]					
	Ecological Impact [Does it reduce footprint?]					
Fence + Gate 'A'	Aesthetics [Is the design marketable?]					
	Affordability [Is pricing competitive?]					
	Durability [Will the materials last?]					
	Efficiency [Is waste use maximized?]					
	Ecological Impact [Does it reduce footprint?]					
Seating 'A'	Aesthetics [Is the design marketable?]					
	Affordability [Is pricing competitive?]					
	Durability [Will the materials last?]					
	Efficiency [Is waste use maximized?]					
	Ecological Impact [Does it reduce footprint?]					
Raised Bed 'A'	Aesthetics [Is the design marketable?]					
	Affordability [Is pricing competitive?]					
	Durability [Will the materials last?]					
	Efficiency [Is waste use maximized?]					
	Ecological Impact [Does it reduce footprint?]					

Reuse Construction Survey

Instructions: Rank each landscape item listed at the left according to corresponding design criteria on a scale from 1-5, 1 meaning that the particular item being assessed is least effective and 5 meaning that the item being assessed is most effective .

Item	Criteria	1	2	3	4	5
Tool Shed 'B'	Aesthetics [Is the design marketable?]					
	Affordability [Is pricing competitive?]					
	Durability [Will the materials last?]					
	Efficiency [Is waste use maximized?]					
	Ecological Impact [Does it reduce footprint?]					
Fence + Gate 'B'	Aesthetics [Is the design marketable?]					
	Affordability [Is pricing competitive?]					
	Durability [Will the materials last?]					
	Efficiency [Is waste use maximized?]					
	Ecological Impact [Does it reduce footprint?]					
Seating 'B'	Aesthetics [Is the design marketable?]					
	Affordability [Is pricing competitive?]					
	Durability [Will the materials last?]					
	Efficiency [Is waste use maximized?]					
	Ecological Impact [Does it reduce footprint?]					
Raised Bed 'B'	Aesthetics [Is the design marketable?]					
	Affordability [Is pricing competitive?]					
	Durability [Will the materials last?]					
	Efficiency [Is waste use maximized?]					
	Ecological Impact [Does it reduce footprint?]					

Reuse Construction Survey

Instructions: Rank each landscape item listed at the left according to corresponding design criteria on a scale from 1-5, 1 meaning that the particular item being assessed is least effective and 5 meaning that the item being assessed is most effective .

Item	Criteria	1	2	3	4	5
Tool Shed 'C'	Aesthetics [Is the design marketable?]					
	Affordability [Is pricing competitive?]					
	Durability [Will the materials last?]					
	Efficiency [Is waste use maximized?]					
	Ecological Impact [Does it reduce footprint?]					
Fence + Gate 'C'	Aesthetics [Is the design marketable?]					
	Affordability [Is pricing competitive?]					
	Durability [Will the materials last?]					
	Efficiency [Is waste use maximized?]					
	Ecological Impact [Does it reduce footprint?]					
Seating 'C'	Aesthetics [Is the design marketable?]					
	Affordability [Is pricing competitive?]					
	Durability [Will the materials last?]					
	Efficiency [Is waste use maximized?]					
	Ecological Impact [Does it reduce footprint?]					
Raised Bed 'C'	Aesthetics [Is the design marketable?]					
	Affordability [Is pricing competitive?]					
	Durability [Will the materials last?]					
	Efficiency [Is waste use maximized?]					
	Ecological Impact [Does it reduce footprint?]					

APPENDIX B:

STUDY SURVEY RESULTS

Reuse Construction Survey

Instructions: Rank each landscape item listed at the left according to corresponding design criteria on a scale from 1-5, 1 meaning that the particular item being assessed is least effective and 5 meaning that the item being assessed is most effective .

WOODSCRAPS

Item	Criteria	1	2	3	4	5
Tool Shed 'A'	Aesthetics [Is the design marketable?]					✓
	Affordability [Is pricing competitive?]				✓	
	Durability [Will the materials last?]				✓	
	Efficiency [Is waste use maximized?]			✓		
	Ecological Impact [Does it reduce footprint?]				✓	
Fence + Gate 'A'	Aesthetics [Is the design marketable?]					✓
	Affordability [Is pricing competitive?]			✓		
	Durability [Will the materials last?]				✓	
	Efficiency [Is waste use maximized?]					✓
	Ecological Impact [Does it reduce footprint?]					✓
~~Seating 'A'~~	~~Aesthetics [Is the design marketable?]~~					
	~~Affordability [Is pricing competitive?]~~					
	~~Durability [Will the materials last?]~~					
	~~Efficiency [Is waste use maximized?]~~					
	~~Ecological Impact [Does it reduce footprint?]~~					
Raised Bed 'A'	Aesthetics [Is the design marketable?]					✓
	Affordability [Is pricing competitive?]					✓
	Durability [Will the materials last?]			✓		
	Efficiency [Is waste use maximized?]					✓
	Ecological Impact [Does it reduce footprint?]					✓

Reuse Construction Survey

Instructions: Rank each landscape item listed at the left according to corresponding design criteria on a scale from 1-5, 1 meaning that the particular item being assessed is least effective and 5 meaning that the item being assessed is most effective.

BARN / DIMENSIONAL LUMB.

Item	Criteria	1	2	3	4	5
Tool Shed 'B'	Aesthetics [Is the design marketable?]					✓
	Affordability [Is pricing competitive?]					✓
	Durability [Will the materials last?]					✓
	Efficiency [Is waste use maximized?]					✓
	Ecological Impact [Does it reduce footprint?]					✓
Fence + Gate 'B'	Aesthetics [Is the design marketable?]				✓	
	Affordability [Is pricing competitive?]			✓		
	Durability [Will the materials last?]					✓
	Efficiency [Is waste use maximized?]					✓
	Ecological Impact [Does it reduce footprint?]					✓
Seating 'B'	Aesthetics [Is the design marketable?]					
	Affordability [Is pricing competitive?]					
	Durability [Will the materials last?]					
	Efficiency [Is waste use maximized?]					
	Ecological Impact [Does it reduce footprint?]					
Raised Bed 'B'	Aesthetics [Is the design marketable?]					✓
	Affordability [Is pricing competitive?]					✓
	Durability [Will the materials last?]				✓	
	Efficiency [Is waste use maximized?]					✓
	Ecological Impact [Does it reduce footprint?]					✓

Reuse Construction Survey

Instructions: Rank each landscape item listed at the left according to corresponding design criteria on a scale from 1-5, 1 meaning that the particular item being assessed is least effective and 5 meaning that the item being assessed is most effective.

PALETTES

Item	Criteria	1	2	3	4	5
Tool Shed 'C'	Aesthetics [Is the design marketable?]			✓		
	Affordability [Is pricing competitive?]					✓
	Durability [Will the materials last?]					✓
	Efficiency [Is waste use maximized?]					✓
	Ecological Impact [Does it reduce footprint?]					✓
Fence + Gate 'C'	Aesthetics [Is the design marketable?]			✓		
	Affordability [Is pricing competitive?]				✓	
	Durability [Will the materials last?]					✓
	Efficiency [Is waste use maximized?]					✓
	Ecological Impact [Does it reduce footprint?]					✓
Seating 'C'	Aesthetics [Is the design marketable?]					
	Affordability [Is pricing competitive?]					
	Durability [Will the materials last?]					
	Efficiency [Is waste use maximized?]					
	Ecological Impact [Does it reduce footprint?]					
Raised Bed 'C'	Aesthetics [Is the design marketable?]			✓		
	Affordability [Is pricing competitive?]					✓
	Durability [Will the materials last?]					✓
	Efficiency [Is waste use maximized?]					✓
	Ecological Impact [Does it reduce footprint?]					✓

Reuse Construction Survey

Instructions: Rank each landscape item listed at the left according to corresponding design criteria on a scale from 1-5, 1 meaning that the particular item being assessed is least effective and 5 meaning that the item being assessed is most effective .

Item	Criteria	1	2	3	4	5
Tool Shed 'LOWES'	Aesthetics [Is the design marketable?]				✓	
	Affordability [Is pricing competitive?]					✓
	Durability [Will the materials last?]					✓
	Efficiency [Is waste use maximized?]		✓			
	Ecological Impact [Does it reduce footprint?]	✓				
Fence + Gate 'LOWES'	Aesthetics [Is the design marketable?]	✓				
	Affordability [Is pricing competitive?]					✓
	Durability [Will the materials last?]					✓
	Efficiency [Is waste use maximized?]		✓			
	Ecological Impact [Does it reduce footprint?]	✓				
~~Seating 'C'~~	~~Aesthetics [Is the design marketable?]~~					
	~~Affordability [Is pricing competitive?]~~					
	~~Durability [Will the materials last?]~~					
	~~Efficiency [Is waste use maximized?]~~					
	~~Ecological Impact [Does it reduce footprint?]~~					
Raised Bed 'LOWES'	Aesthetics [Is the design marketable?]				✓	
	Affordability [Is pricing competitive?]			✓		
	Durability [Will the materials last?]			✓		
	Efficiency [Is waste use maximized?]		✓			
	Ecological Impact [Does it reduce footprint?]	✓				

Instructions: Rank each landscape item listed at the left according to corresponding design criteria on a scale from 1-5, 1 meaning that the particular item being assessed is least effective and 5 meaning that the item being assessed is most effective .

least effect > A ——> most effect

Item	Criteria	1	2	3	4	5
Tool Shed 'A' good in well maintained garden	**Aesthetics** [Is the design marketable?]				✓	
more material is used in wall, than necessary	**Affordability** [Is pricing competitive?]		✓			
the roof overhang is essential for moisture	**Durability** [Will the materials last?]				✓	
lots of material	**Efficiency** [Is waste use maximized?]		✓			
	Ecological Impact [Does it reduce footprint?]			✓		
Fence + Gate 'A' good in well maintained garden	**Aesthetics** [Is the design marketable?]				✓	
	Affordability [Is pricing competitive?]				✓	
untreated wood — particularly on top piece	**Durability** [Will the materials last?]		✓			
	Efficiency [Is waste use maximized?]				✓	
	Ecological Impact [Does it reduce footprint?]			✓		
Seating 'A'	**Aesthetics** [Is the design marketable?]					
	Affordability [Is pricing competitive?]					
	Durability [Will the materials last?]					
	Efficiency [Is waste use maximized?]					
	Ecological Impact [Does it reduce footprint?]					
Raised Bed 'A'	**Aesthetics** [Is the design marketable?]				✓	
	Affordability [Is pricing competitive?]				✓	
exposure to rain; contact with ground; wet soil inside	**Durability** [Will the materials last?]	✓				
	Efficiency [Is waste use maximized?]				✓	
In my view, manufactured materials are not as inefficient as LEED says	**Ecological Impact** [Does it reduce footprint?]			✓		

Bruce F.

...euse Construction Survey

Instructions: Rank each landscape item listed at the left according to corresponding design criteria on a scale from 1-5, 1 meaning that the particular item being assessed is least effective and 5 meaning that the item being assessed is most effective .

least effect → most effect

Item	Criteria	1	2	3	4	5
Tool Shed 'B' good or well maintained garden →	Aesthetics [Is the design marketable?]				✓	
labor for stick-built construction	Affordability [Is pricing competitive?]			✓	~~✓~~	~~✓~~
~~same issue of sunlight~~	Durability [Will the materials last?]	~~✓~~			✓	
	Efficiency [Is waste use maximized?]					✓
	Ecological Impact [Does it reduce footprint?]			✓		
Fence + Gate 'B'	Aesthetics [Is the design marketable?]				✓	
	Affordability [Is pricing competitive?]				✓	
exposure to rain & sunlight	Durability [Will the materials last?]	✓				
	Efficiency [Is waste use maximized?]					✓
	Ecological Impact [Does it reduce footprint?]			✓		
Seating 'B'	Aesthetics [Is the design marketable?]					
	Affordability [Is pricing competitive?]					
	Durability [Will the materials last?]					
	Efficiency [Is waste use maximized?]					
	Ecological Impact [Does it reduce footprint?]					
Raised Bed 'B'	Aesthetics [Is the design marketable?]				✓	
	Affordability [Is pricing competitive?]				✓	
same as bed 'A'	Durability [Will the materials last?]	✓				
	Efficiency [Is waste use maximized?]				✓	
	Ecological Impact [Does it reduce footprint?]			✓		

Dave F.

euse Construction Survey

Instructions: Rank each landscape item listed at the left according to corresponding design criteria on a scale from 1-5, 1 meaning that the particular item being assessed is least effective and 5 meaning that the item being assessed is most effective.

least effective → most effective

Item	Criteria	1	2	3	4	5
Tool Shed 'C' ~~irregular~~ choppy look	Aesthetics [Is the design marketable?]	~~✓~~	✓			
	Affordability [Is pricing competitive?]				✓	
	Durability [Will the materials last?]				✓	
	Efficiency [Is waste use maximized?]					✓
	Ecological Impact [Does it reduce footprint?]			✓		
Fence + Gate 'C' irregular choppy look	Aesthetics [Is the design marketable?]	✓				
	Affordability [Is pricing competitive?]				✓	
lots of exposure to water	Durability [Will the materials last?]	✓				
	Efficiency [Is waste use maximized?]					✓
	Ecological Impact [Does it reduce footprint?]			✓		
Seating 'C'	Aesthetics [Is the design marketable?]					
	Affordability [Is pricing competitive?]					
	Durability [Will the materials last?]					
	Efficiency [Is waste use maximized?]					
	Ecological Impact [Does it reduce footprint?]					
Raised Bed 'C' choppy look	Aesthetics [Is the design marketable?]			✓		
	Affordability [Is pricing competitive?]				✓	
same as bed 'A'	Durability [Will the materials last?]	✓				
	Efficiency [Is waste use maximized?]				✓	
	Ecological Impact [Does it reduce footprint?]			✓		

Bruce F.

euse Construction Survey

Instructions: Rank each landscape item listed at the left according to corresponding design criteria on a scale from 1-5, 1 meaning that the particular item being assessed is least effective and 5 meaning that the item being assessed is most effective.

least effect. ←→ most effect.

Item	Criteria	1	2	3	4	5
Tool Shed 'LOWES' cheaply dressed up	Aesthetics [Is the design marketable?]		✓			
	Affordability [Is pricing competitive?]			✓		
	Durability [Will the materials last?]					✓
depends on manufacturing process	Efficiency [Is waste use maximized?]				✓	
	Ecological Impact [Does it reduce footprint?]			✓		
Fence + Gate 'LOWES' depends on context	Aesthetics [Is the design marketable?]				✓	
	Affordability [Is pricing competitive?]			✓		
PT matters	Durability [Will the materials last?]					✓
	Efficiency [Is waste use maximized?]				✓	
	Ecological Impact [Does it reduce footprint?]			✓		
~~Seating 'A'~~	~~Aesthetics [Is the design marketable?]~~					
	~~Affordability [Is pricing competitive?]~~					
	~~Durability [Will the materials last?]~~					
	~~Efficiency [Is waste use maximized?]~~					
	~~Ecological Impact [Does it reduce footprint?]~~					
Raised Bed 'LOWES' ~~cedar made~~	Aesthetics [Is the design marketable?]				✓	
	Affordability [Is pricing competitive?]			✓		
cedar is relatively weather-resistant	Durability [Will the materials last?]				✓	
	Efficiency [Is waste use maximized?]				✓	
	Ecological Impact [Does it reduce footprint?]			✓		

Reuse Construction Survey

Instructions: Rank each landscape item listed at the left according to corresponding design criteria on a scale from 1-5, 1 meaning that the particular item being assessed is least effective and 5 meaning that the item being assessed is most effective .

Item	Criteria	1	2	3	4	5
Tool Shed 'A'	Aesthetics [Is the design marketable?]					X
	Affordability [Is pricing competitive?]			X		
	Durability [Will the materials last?]				X	
	Efficiency [Is waste use maximized?]			X		
	Ecological Impact [Does it reduce footprint?]				X	
Fence + Gate 'A'	Aesthetics [Is the design marketable?]					X
	Affordability [Is pricing competitive?]				X	
	Durability [Will the materials last?]			X		
	Efficiency [Is waste use maximized?]				X	
	Ecological Impact [Does it reduce footprint?]				X	
~~Seating 'A'~~	~~Aesthetics [Is the design marketable?]~~					
	~~Affordability [Is pricing competitive?]~~					
	~~Durability [Will the materials last?]~~					
	~~Efficiency [Is waste use maximized?]~~					
	~~Ecological Impact [Does it reduce footprint?]~~					
Raised Bed 'A'	Aesthetics [Is the design marketable?]					X
	Affordability [Is pricing competitive?]					X
	Durability [Will the materials last?]		X			
	Efficiency [Is waste use maximized?]				X	
	Ecological Impact [Does it reduce footprint?]				X	

…euse Construction Survey

Instructions: Rank each landscape item listed at the left according to corresponding design criteria on a scale from 1-5, 1 meaning that the particular item being assessed is least effective and 5 meaning that the item being assessed is most effective.

Item	Criteria	1	2	3	4	5
Tool Shed 'B'	Aesthetics [Is the design marketable?]				X	
	Affordability [Is pricing competitive?]				X	
	Durability [Will the materials last?]				X	
	Efficiency [Is waste use maximized?]				X	
	Ecological Impact [Does it reduce footprint?]				X	
Fence + Gate 'B'	Aesthetics [Is the design marketable?]				X	
	Affordability [Is pricing competitive?]			X		
	Durability [Will the materials last?]			X		
	Efficiency [Is waste use maximized?]				X	
	Ecological Impact [Does it reduce footprint?]				X	
Seating 'B'	Aesthetics [Is the design marketable?]					
	Affordability [Is pricing competitive?]					
	Durability [Will the materials last?]					
	Efficiency [Is waste use maximized?]					
	Ecological Impact [Does it reduce footprint?]					
Raised Bed 'B'	Aesthetics [Is the design marketable?]				X	
	Affordability [Is pricing competitive?]					X
	Durability [Will the materials last?]				X	
	Efficiency [Is waste use maximized?]				X	
	Ecological Impact [Does it reduce footprint?]				X	

Instructions: Rank each landscape item listed at the left according to corresponding design criteria on a scale from 1-5, 1 meaning that the particular item being assessed is least effective and 5 meaning that the item being assessed is most effective .

Item	Criteria	1	2	3	4	5
Tool Shed 'C'	Aesthetics [Is the design marketable?]			X		
	Affordability [Is pricing competitive?]				X	
	Durability [Will the materials last?]			X		
	Efficiency [Is waste use maximized?]					X
	Ecological Impact [Does it reduce footprint?]					X
Fence + Gate 'C'	Aesthetics [Is the design marketable?]			X		
	Affordability [Is pricing competitive?]					X
	Durability [Will the materials last?]		X			
	Efficiency [Is waste use maximized?]					X
	Ecological Impact [Does it reduce footprint?]					X
~~Seating 'C'~~	Aesthetics [Is the design marketable?]					
	Affordability [Is pricing competitive?]					
	Durability [Will the materials last?]					
	Efficiency [Is waste use maximized?]					
	Ecological Impact [Does it reduce footprint?]					
Raised Bed 'C'	Aesthetics [Is the design marketable?]			X		
	Affordability [Is pricing competitive?]					X
	Durability [Will the materials last?]		X			
	Efficiency [Is waste use maximized?]					X
	Ecological Impact [Does it reduce footprint?]					X

Reuse Construction Survey

Instructions: Rank each landscape item listed at the left according to corresponding design criteria on a scale from 1-5, 1 meaning that the particular item being assessed is least effective and 5 meaning that the item being assessed is most effective.

Item	Criteria	1	2	3	4	5
Tool Shed 'LOWES'	Aesthetics [Is the design marketable?]			X		
	Affordability [Is pricing competitive?]			X		
	Durability [Will the materials last?]				X	
	Efficiency [Is waste use maximized?]			X		
	Ecological Impact [Does it reduce footprint?]		X			
Fence + Gate 'LOWES'	Aesthetics [Is the design marketable?]		X			
	Affordability [Is pricing competitive?]				X	
	Durability [Will the materials last?]			X		
	Efficiency [Is waste use maximized?]			X		
	Ecological Impact [Does it reduce footprint?]		X			
~~Seating~~ 'C'	Aesthetics [Is the design marketable?]					
	Affordability [Is pricing competitive?]					
	Durability [Will the materials last?]					
	Efficiency [Is waste use maximized?]					
	Ecological Impact [Does it reduce footprint?]					
Raised Bed 'LOWES'	Aesthetics [Is the design marketable?]			X		
	Affordability [Is pricing competitive?]			X		
	Durability [Will the materials last?]			X		
	Efficiency [Is waste use maximized?]		X			
	Ecological Impact [Does it reduce footprint?]		X			

Reuse Construction Survey

Instructions: Rank each landscape item listed at the left according to corresponding design criteria on a scale from 1-5, 1 meaning that the particular item being assessed is least effective and 5 meaning that the item being assessed is most effective.

Geo Wright

Item	Criteria	1	2	3	4	5
Tool Shed 'A'	Aesthetics [Is the design marketable?]					X
	Affordability [Is pricing competitive?]					X
	Durability [Will the materials last?]				X	
	Efficiency [Is waste use maximized?]					X
	Ecological Impact [Does it reduce footprint?]					X
Fence + Gate 'A'	Aesthetics [Is the design marketable?]					X
	Affordability [Is pricing competitive?]					X
	Durability [Will the materials last?]				X	
	Efficiency [Is waste use maximized?]					X
	Ecological Impact [Does it reduce footprint?]					X
Seating 'A'	Aesthetics [Is the design marketable?]					
	Affordability [Is pricing competitive?]					
	Durability [Will the materials last?]					
	Efficiency [Is waste use maximized?]					
	Ecological Impact [Does it reduce footprint?]					
Raised Bed 'A'	Aesthetics [Is the design marketable?]					X
	Affordability [Is pricing competitive?]				X	
	Durability [Will the materials last?]				X	
	Efficiency [Is waste use maximized?]					X
	Ecological Impact [Does it reduce footprint?]					X

Instructions: Rank each landscape item listed at the left according to corresponding design criteria on a scale from 1-5, 1 meaning that the particular item being assessed is least effective and 5 meaning that the item being assessed is most effective .

Geo Wright

Item	Criteria	1	2	3	4	5
Tool Shed 'B'	Aesthetics [Is the design marketable?]				X	
	Affordability [Is pricing competitive?]		X			
	Durability [Will the materials last?]				X	
	Efficiency [Is waste use maximized?]				X	
	Ecological Impact [Does it reduce footprint?]					X
Fence + Gate 'B'	Aesthetics [Is the design marketable?]				X	
	Affordability [Is pricing competitive?]				X	
	Durability [Will the materials last?]				X	
	Efficiency [Is waste use maximized?]				X	\
	Ecological Impact [Does it reduce footprint?]					X
Seating 'B'	Aesthetics [Is the design marketable?]					~~X~~
	Affordability [Is pricing competitive?]					
	Durability [Will the materials last?]					
	Efficiency [Is waste use maximized?]					
	Ecological Impact [Does it reduce footprint?]					
Raised Bed 'B'	Aesthetics [Is the design marketable?]					X
	Affordability [Is pricing competitive?]				X	
	Durability [Will the materials last?]				X	
	Efficiency [Is waste use maximized?]					X
	Ecological Impact [Does it reduce footprint?]					X

Instructions: Rank each landscape item listed at the left according to corresponding design criteria on a scale from 1-5, 1 meaning that the particular item being assessed is least effective and 5 meaning that the item being assessed is most effective.

[illegible]

Item	Criteria	1	2	3	4	5
Tool Shed 'C'	Aesthetics [Is the design marketable?]		X			
	Affordability [Is pricing competitive?]			X		
	Durability [Will the materials last?]			X		
	Efficiency [Is waste use maximized?]					X
	Ecological Impact [Does it reduce footprint?]					X
Fence + Gate 'C'	Aesthetics [Is the design marketable?]			X		
	Affordability [Is pricing competitive?]	X				
	Durability [Will the materials last?]			X		
	Efficiency [Is waste use maximized?]					X
	Ecological Impact [Does it reduce footprint?]					X
Seating 'C'	Aesthetics [Is the design marketable?]					
	Affordability [Is pricing competitive?]					
	Durability [Will the materials last?]					
	Efficiency [Is waste use maximized?]					
	Ecological Impact [Does it reduce footprint?]					
Raised Bed 'C'	Aesthetics [Is the design marketable?]				X	
	Affordability [Is pricing competitive?]		X			
	Durability [Will the materials last?]			X		
	Efficiency [Is waste use maximized?]					X
	Ecological Impact [Does it reduce footprint?]					X

Reuse Construction Survey

Instructions: Rank each landscape item listed at the left according to corresponding design criteria on a scale from 1-5, 1 meaning that the particular item being assessed is least effective and 5 meaning that the item being assessed is most effective.

Dea Wright

Item	Criteria	1	2	3	4	5
Tool Shed 'LOWES'	Aesthetics [Is the design marketable?]			X		
	Affordability [Is pricing competitive?]				X	
	Durability [Will the materials last?]				X	
	Efficiency [Is waste use maximized?]	X				
	Ecological Impact [Does it reduce footprint?]	X				
Fence + Gate 'LOWES'	Aesthetics [Is the design marketable?]				X	
	Affordability [Is pricing competitive?]					X
	Durability [Will the materials last?]		X			
	Efficiency [Is waste use maximized?]	X				
	Ecological Impact [Does it reduce footprint?]	X				
~~Seating 'A'~~	~~Aesthetics [Is the design marketable?]~~					
	~~Affordability [Is pricing competitive?]~~					
	~~Durability [Will the materials last?]~~					
	~~Efficiency [Is waste use maximized?]~~					
	~~Ecological Impact [Does it reduce footprint?]~~					
Raised Bed 'LOWES'	Aesthetics [Is the design marketable?]				X	
	Affordability [Is pricing competitive?]			X		
	Durability [Will the materials last?]				X	
	Efficiency [Is waste use maximized?]	X				
	Ecological Impact [Does it reduce footprint?]	X				

Instructions: Rank each landscape item listed at the left according to corresponding design criteria on a scale from 1-5, 1 meaning that the particular item being assessed is least effective and 5 meaning that the item being assessed is most effective .

Item	Criteria	1	2	3	4	5
Tool Shed 'A'	Aesthetics [Is the design marketable?]					✓
	Affordability [Is pricing competitive?]		✓			
	Durability [Will the materials last?]					✓
	Efficiency [Is waste use maximized?]					✓
	Ecological Impact [Does it reduce footprint?]					✓
Fence + Gate 'A'	Aesthetics [Is the design marketable?]					✓
	Affordability [Is pricing competitive?]			✓		
	Durability [Will the materials last?]				✓	
	Efficiency [Is waste use maximized?]					✓
	Ecological Impact [Does it reduce footprint?]					✓
Seating 'A'	Aesthetics [Is the design marketable?]					
	Affordability [Is pricing competitive?]					
	Durability [Will the materials last?]					
	Efficiency [Is waste use maximized?]					
	Ecological Impact [Does it reduce footprint?]					
Raised Bed 'A'	Aesthetics [Is the design marketable?]					✓
	Affordability [Is pricing competitive?]					✓
	Durability [Will the materials last?]			✓		
	Efficiency [Is waste use maximized?]					✓
	Ecological Impact [Does it reduce footprint?]					✓

use Construction Survey

Instructions: Rank each landscape item listed at the left according to corresponding design criteria on a scale from 1-5, 1 meaning that the particular item being assessed is least effective and 5 meaning that the item being assessed is most effective .

Item	Criteria	1	2	3	4	5
Tool Shed 'B'	Aesthetics [Is the design marketable?]					✓
	Affordability [Is pricing competitive?]					✓
	Durability [Will the materials last?]					✓
	Efficiency [Is waste use maximized?]					✓
	Ecological Impact [Does it reduce footprint?]					✓
Fence + Gate 'B'	Aesthetics [Is the design marketable?]					✓
	Affordability [Is pricing competitive?]		✓			
	Durability [Will the materials last?]					✓
	Efficiency [Is waste use maximized?]					✓
	Ecological Impact [Does it reduce footprint?]					✓
~~Seating 'B'~~	~~Aesthetics [Is the design marketable?]~~					
	~~Affordability [Is pricing competitive?]~~					
	~~Durability [Will the materials last?]~~					
	~~Efficiency [Is waste use maximized?]~~					
	~~Ecological Impact [Does it reduce footprint?]~~					
Raised Bed 'B'	Aesthetics [Is the design marketable?]				✓	
	Affordability [Is pricing competitive?]					✓
	Durability [Will the materials last?]			✓		
	Efficiency [Is waste use maximized?]				✓	
	Ecological Impact [Does it reduce footprint?]					✓

euse Construction Survey

Instructions: Rank each landscape item listed at the left according to corresponding design criteria on a scale from 1-5, 1 meaning that the particular item being assessed is least effective and 5 meaning that the item being assessed is most effective.

Item	Criteria	1	2	3	4	5
Tool Shed 'C'	Aesthetics [Is the design marketable?]		✓			
	Affordability [Is pricing competitive?]					✓
	Durability [Will the materials last?]			✓		
	Efficiency [Is waste use maximized?]				✓	
	Ecological Impact [Does it reduce footprint?]				✓	
Fence + Gate 'C'	Aesthetics [Is the design marketable?]		✓			
	Affordability [Is pricing competitive?]				✓	
	Durability [Will the materials last?]			✓		
	Efficiency [Is waste use maximized?]					✓
	Ecological Impact [Does it reduce footprint?]					✓
Seating 'C'	Aesthetics [Is the design marketable?]					
	Affordability [Is pricing competitive?]					
	Durability [Will the materials last?]					
	Efficiency [Is waste use maximized?]					
	Ecological Impact [Does it reduce footprint?]					
Raised Bed 'C'	Aesthetics [Is the design marketable?]		✓			
	Affordability [Is pricing competitive?]					✓
	Durability [Will the materials last?]		✓			
	Efficiency [Is waste use maximized?]				✓	
	Ecological Impact [Does it reduce footprint?]				✓	

euse Construction Survey

Instructions: Rank each landscape item listed at the left according to corresponding design criteria on a scale from 1-5, 1 meaning that the particular item being assessed is least effective and 5 meaning that the item being assessed is most effective .

Item	Criteria	1	2	3	4	5
Tool Shed 'LOWES'	Aesthetics [Is the design marketable?]		✓			
	Affordability [Is pricing competitive?]				✓	
	Durability [Will the materials last?]		✓			
	Efficiency [Is waste use maximized?]	✓				
	Ecological Impact [Does it reduce footprint?]	✓				
Fence + Gate 'LOWES'	Aesthetics [Is the design marketable?]	✓				
	Affordability [Is pricing competitive?]					✓
	Durability [Will the materials last?]		✓			
	Efficiency [Is waste use maximized?]	✓				
	Ecological Impact [Does it reduce footprint?]	✓				
~~Seating 'C'~~	~~Aesthetics [Is the design marketable?]~~					
	~~Affordability [Is pricing competitive?]~~					
	~~Durability [Will the materials last?]~~					
	~~Efficiency [Is waste use maximized?]~~					
	~~Ecological Impact [Does it reduce footprint?]~~					
Raised Bed 'LOWES'	Aesthetics [Is the design marketable?]		✓			
	Affordability [Is pricing competitive?]			✓		
	Durability [Will the materials last?]		✓			
	Efficiency [Is waste use maximized?]	✓				
	Ecological Impact [Does it reduce footprint?]	✓				

APPENDIX C:

SUPPLEMENTAL DATA SHEET

Item	Weight	Hours/Cost	Source/EE	Dimensions	LF Envelope	LF Total	Wood Type	Wood Age
Shed 'A'	1768.1	20/$2400	<20/3	6x8'	996	1543	Pine/HW	Mix
Shed 'B'	1034.4	13/$1620	<20/1	6x8'	168	735	HW	50s
Shed 'C'	855.1	14/$1680	20-50/2	6x8'	170	480	HW	Mod
Shed 'Lowes'	770	8/$1899	500-2000/4	7x7'	n/a	n/a	W. Cedar	Mod
Fence 'A'	251.5	2/$120	<20/3	5x8'	96	151	Pine	Mix
Fence 'B'	126	1/$120	<20/2	5x8'	56	87	HW	50s
Fence 'C'	149.4	1/$90	<20/1	5x8'	60	148	HW	Mod
Fence 'Lowes'	140	1/$52	>500/4	6x8'	120	152	Pine PT	Mod
Gate 'A'	39.8	1.5/$90	<20/3	45"x6' H	66	101	Pine	Antique
Gate 'B'	41.6	1.5/$120	<20/2	46"x5' H	30	51	HW	50s
Gate 'C'	27.2	1.5/$75	<20/1	44"x5' H	60	81	HW	Mod
Bed 'A'	139.2	1/$120	<20/1	24x60"	64	72	Pine	Mix
Bed 'B'	137.6	1/$120	<20/3	36x60"	36	76	Pine	Mix
Bed 'C'	124	1/$120	<20/2	28x60"	88	150	Pine/HW	Ant/Mod
Bed 'Lowes'	95	1/$152	500-2000/4	24x60"	64	72	W. Cedar	Mod

Item	Landscape Item
Weight	Total Weight of Structure
Hours	Estimated Hours of Construction
Cost	Estimated Cost (Construction + Salvage + Materials)
Source	Origin of Wood in Miles
EE	Embodied Energy Ranking
Dimensions	Square Foot Dimensions
LF Envelope	Total Linear Footage of Wood in Envelope
LF Total	Total Linear Footage of Wood in Structure
Wood Type	Species of Wood
Wood Age	Era of Wood

APPENDIX D:

EMBODIED ENERGY CALCULATIONS

Embodied Energy Wall Comparison

Wall Volume

length	6 ft
height	6 ft

Basic Embodied Energy

std. width	(in feet)	wood type	bt/lb.	weight	**total**
shed 'A' (4")	0.33	softwood - AD	499	218	**108,782**
shed 'B' (1")	0.08	hardwood - AD	602	93	**55,986**
shed 'C' (1.25")	0.1	hardwood - AD	602	120	**72,240**
shed 'L' (0.75")	0.06	softwood - AD	499	77	**38,423**

Total Embodied Energy

Transportation

	pct/ton	miles	btu/ton/mi	**total**
shed 'A'	0.109	10	255	**2550**
shed 'B'	0.05	20	109	**2176**
shed 'C'	0.06	5	140	**702**
shed 'L'	0.038	2670	236	**631,161**

Production

	hrs	btu/hr (chopsaw)	**total**
shed 'A'	4.28	5660	**24,224**
shed 'B'	2.78	5660	**15,734**
shed 'C'	3	5660	**16,980**
shed 'L'	1.7	5660	**9,622**

Total	**btu's/100 LF**	**Ranking**
shed 'A'	**135,556**	**3**
shed 'B'	**73,896**	**1**
shed 'C'	**89,922**	**2**
shed 'L'	**679,206**	**4**

APPENDIX E:

WARM MODEL CALCULATIONS

Energy Use Analysis — Summary Report

(Version 12, 2/12)

Analysis of Energy Use from Waste Management

Energy Use from Baseline Waste Management Scenario (million BTU):	1,902
Energy Use from Alternative Waste Management Scenario (million BTU):	-20,236
Total Change in Energy Use (million BTU):	**-22,139**

	Baseline Scenario					Alternative Scenario						
Material	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Million BTU	Tons Source Reduced	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Million BTU	Change (Alt - Base) Million BTU
Dimensional Lumber	0	5,732	0	N/A	1,902	5,732	0	0	0	N/A	-20,236	**-22,139**

This is equivalent to...

Conserving 197 Households' Annual Energy Consumption

Conserving 3,810 Barrels of Oil

Conserving 177,110 Gallons of Gasoline

Energy Use Analysis — Summary Report

(Version 12, 2/12)

Analysis of Energy Use from Waste Management

Energy Use from Baseline Waste Management Scenario (million BTU):	3,413
Energy Use from Alternative Waste Management Scenario (million BTU):	-20,236
Total Change in Energy Use (million BTU):	**-23,649**

	Baseline Scenario					Alternative Scenario						
Material	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Million BTU	Tons Source Reduced	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Million BTU	Change (Alt - Base) Million BTU
Dimensional Lumber	5,732	0	0	N/A	3,413	5,732	0	0	0	N/A	-20,236	**-23,649**

This is equivalent to...

Conserving 210 Households' Annual Energy Consumption

Conserving 4,070 Barrels of Oil

Conserving 189,192 Gallons of Gasoline

Energy Use Analysis — Summary Report

(Version 12, 2/12)

Analysis of Energy Use from Waste Management

Energy Use from Baseline Waste Management Scenario (million BTU):	-45,566
Energy Use from Alternative Waste Management Scenario (million BTU):	-20,236
Total Change in Energy Use (million BTU):	**25,330**

	Baseline Scenario					Alternative Scenario						
Material	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Million BTU	Tons Source Reduced	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Million BTU	Change (Alt - Base) Million BTU
Dimensional Lumber	0	0	5,732	N/A	-45,566	5,732	0	0	0	N/A	-20,236	**25,330**

This is equivalent to...

Consuming 225 Households' Annual Energy Consumption

Consuming 4,360 Barrels of Oil

Consuming 202,636 Gallons of Gasoline

GHG Emissions Analysis — Summary Report

(Version 12, 2/12)

Analysis of GHG Emissions from Waste Management

GHG Emissions from Baseline Waste Management Scenario (MTCO2E):	-4,163
GHG Emissions from Alternative Waste Management Scenario (MTCO2E):	-11,578
Total Change in GHG Emissions: (MTCO2E):	**-7,416**

	Baseline Scenario					Alternative Scenario						
Material	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Total MTCO2E	Tons Source Reduced	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Total MTCO2E	Change (Alt - Base) MTCO2E
Dimensional Lumber	0	5,732	0	N/A	-4,163	5,732	0	0	0	N/A	-11,578	**-7,416**

Note: A negative value indicates an emission reduction; a positive value indicates an emission increase.
a) For an explanation of the methodology used to develop emission factors, see EPA report: Greenhouse Gas Emissions from Management of Selected Materials in Municipal Solid Waste (EPA530-R-98-013) — available on the Internet at http://www.epa.gov/climatechange/wycd/waste/reports.html Please note that some of the emission factors used to generate these results do not match those presented in the report due to recent additions and/or revisions.
b) Emissions estimates provided by this model are intended to support voluntary GHG measurement and reporting initiatives.
c) Total emissions estimates provided by this model may not sum due to independent rounding.

GHG Emissions Analysis — Summary Report

(Version 12, 2/12)

Analysis of GHG Emissions from Waste Management

GHG Emissions from Baseline Waste Management Scenario (MTCO2E):	-14,081
GHG Emissions from Alternative Waste Management Scenario (MTCO2E):	-11,578
Total Change in GHG Emissions: (MTCO2E):	**2,503**

	Baseline Scenario					Alternative Scenario						
Material	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Total MTCO2E	Tons Source Reduced	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Total MTCO2E	Change (Alt - Base) MTCO2E
Dimensional Lumber	5,732	0	0	N/A	-14,081	5,732	0	0	0	N/A	-11,578	**2,503**

Note: A negative value indicates an emission reduction; a positive value indicates an emission increase.
a) For an explanation of the methodology used to develop emission factors, see EPA report: Greenhouse Gas Emissions from Management of Selected Materials in Municipal Solid Waste (EPA530-R-98-013) — available on the Internet at http://www.epa.gov/climatechange/wycd/waste/reports.html Please note that some of the emission factors used to generate these results do not match those presented in the report due to recent additions and/or revisions.
b) Emissions estimates provided by this model are intended to support voluntary GHG measurement and reporting initiatives.
c) Total emissions estimates provided by this model may not sum due to independent rounding.

GHG Emissions Analysis — Summary Report

(Version 12, 2/12)

Analysis of GHG Emissions from Waste Management

GHG Emissions from Baseline Waste Management Scenario (MTCO2E):	-3,331
GHG Emissions from Alternative Waste Management Scenario (MTCO2E):	-11,578
Total Change in GHG Emissions: (MTCO2E):	**-8,247**

	Baseline Scenario					Alternative Scenario						
Material	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Total MTCO2E	Tons Source Reduced	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Total MTCO2E	Change (Alt - Base) MTCO2E
Dimensional Lumber	0	0	5,732	N/A	-3,331	5,732	0	0	0	N/A	-11,578	**-8,247**

Note: A negative value indicates an emission reduction; a positive value indicates an emission increase.
a) For an explanation of the methodology used to develop emission factors, see EPA report: Greenhouse Gas Emissions from Management of Selected Materials in Municipal Solid Waste (EPA530-R-98-013) — available on the Internet at http://www.epa.gov/climatechange/wycd/waste/reports.html Please note that some of the emission factors used to generate these results do not match those presented in the report due to recent additions and/or revisions.
b) Emissions estimates provided by this model are intended to support voluntary GHG measurement and reporting initiatives.
c) Total emissions estimates provided by this model may not sum due to independent rounding.