IMPROVING THE LEED-NC 2009 MATERIALS & RESOURCES CATEGORY USING INTERNATIONAL BUILDING ASSESSMENT SYSTEMS AND STANDARDS

By

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For my friends, family, and Russ DeVore

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Since 1998, the United States Green Building Council's Leadership in Energy and Environment Design (LEED) rating system has dominated the market for building assessment standards within the United States as a result of its consensus-based, market-driven principles. However, there are building assessment systems throughout the world that exemplify higher standards and methodologies for reducing the environmental impacts (e.g., Carbon emissions and ozone layer depletion) of the built environment. This study attempts to learn from other building rating systems and improve upon the materials and resources (MR) category of LEED 2009 resulting in recommendations to the USGBC technical committee for improvement. These recommendations include an approach to life cycle assessment, implementation of resource conservation through design, and changes to materials selection credits.

CHAPTER 1
INTRODUCTION

Research Objectives

This study compares the materials & resources category of the United States Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED) rating system to that of rating systems and building assessment standards worldwide. Although the mission of the USGBC does not specify environmental responsibility, the objective is to make recommendations to the LEED Technical Advisory Group (TAG) for improving the materials and resources category. These recommendations will attempt to reduce the environmental impacts associated with building construction in the United States. The proposed changes would facilitate a more positive contribution to high performance green building in the areas of waste management, materials selection, building reuse, and resource conservation.

Problem Statement

Although the USGBC has implemented one of the most widely accepted and popular building rating systems in the world, there are other building assessment systems that contribute significantly more to the built environment. Through more stringent standards and different methodologies, rating systems and standards such as the Green Building Institute and ANSI's proposed standard 01-2008P, the German Society for Sustainable Construction Certificate, the ASHRAE standard 189.1p, and the International Initiative for a Sustainable Built Environment's SBTool have demonstrated exemplary performance in facilitating continued sustainable development in their respective countries. Over the past decade, the LEED materials & resources (MR) category relative to other assessment systems has limited the potential positive impacts of environmental responsibility to include building reuse, waste management, materials selection, life cycle assessment (LCA), and design for resource conservation.

Significance of the Research

Although countless studies (e.g., Schedler and Udall's "LEED Is Broken- Let's Fix It" and Murphy's LEEDing from Behind: The Rise and Fall of Green Building) have been performed with regard to the problems associated with LEED, to include its lack of life cycle assessment and design for resource conservation, no research has focused on LEED version 3 and its first attempt at life cycle assessment, in addition to MR category comparisons to other systems. According to Dr. Charles Kibert, Director of the Powell Center for Construction & Environment at the University of Florida, the MR category of LEED is its weakest and has significant potential for improvement.

Limitations

The main limiting factor of this research is comparing the related impacts of MR in LEED certified buildings to that of other buildings using international assessment systems. As a result of differing methodologies, varying climate conditions throughout the world, and subjective claims (e.g., productivity and health increases) related to high performance green building, there is no full proof system for determining the superiority of one rating system to another. Furthermore, research statistics on the most and least sough credits within LEED are from 2003 and are not representative of the exponential increases in green building over the past six years. This research focuses on such statistics from the White Paper on Sustainability 2003 (BD&C) that do not have significant sample sizes (i.e., 38 projects).

CHAPTER 2
LITERATURE REVIEW

This chapter is a collection of knowledge from various sources that gives a basis for understanding of the general concepts and information for which this research is based. A description of the related terms of sustainable development will be addressed, as well as the pertinent details of the building assessment systems that will be analyzed.

Definitions

This section addresses the relevant definitions to the research. Included are sustainable construction, high performance green building, life cycle assessment, design for deconstruction/ disassembly, materials & resources, and building assessment systems.

Sustainable Construction

Sustainable Construction, green, and high performance are often used interchangeably; however, the term sustainable construction most generally addresses the environmental, social, and economic issues of a building in the context of its community. In 1994 an international construction research networking organization known as the Conseil International du Batiment (CIB) defined the goal of sustainable construction as '…creating and operating a healthy built environment based on resource efficiency and ecological design (Kibert 2005).' The (CIB) articulated seven principles of sustainable construction which would inform decision making during each phase of design and construction throughout the life cycle of the building. These principles are listed in Table 2-1, and Figure 2-1 addresses these factors when applied to evaluating the components and other resources needed for construction. The seven principles apply across the entire life cycle of construction, from planning to deconstruction. Additionally, the principles apply to the resources needed to create and operate the built environment during its entire life cycle: land, materials, water, energy, and ecosystems (Kibert 2005).

High performance building and green building have become similar phrases in the United States. Green buildings can be defined as "healthy facilities designed and built in a resource efficient manner, using ecologically based principles (Kibert 2005)," and according to the U.S. Office of Energy Efficiency and Renewable Energy (EERE), a high-performance commercial building "…uses whole-building design to achieve energy, economic, and environmental performance that is substantially better than standard practice." Furthermore, the "High Performance Guidelines: Triangle Region Public Facilities," published by the Triangle J Council of Governments in North Carolina (1999), focuses on three principles: sustainability, a long-term view that balances economics, equity, and environmental impacts, an integrated approach that engages a multidisciplinary team at the outset of a project to work collaboratively throughout, and feedback and data collection which quantifies both the finished facility and the process that created it. This serves to generate improvements in future projects. Finally, the Pennsylvania Governor's Green Government Council (GGGC) defines what makes a building high-performance in its "Guidelines for Creating High-Performance Green Buildings: A Document for Decision Makers" outlined in Table 2-2 (GGGC 1999).

Life Cycle Assessment

Life-cycle assessment *(LCA)* is a method for determining the environmental and resource impacts of a material, a product, or even a whole building over its entire life. All energy, water, and materials resources, as well as all emissions to air, water, and land, are tabulated over the entity’s life cycle. The life cycle, or time period considered in this evaluation, can span the extraction of resources, the manufacturing process, installation in a building, and the item’s ultimate disposal. The assessment also considers the resources needed to transport components from extraction through disposal. LCA is an important, comprehensive approach that examines all impacts of material selection decisions, rather than simply an item’s performance in the building (Kibert 2005). The idea of LCA is conceptualized in Figure 2-2.

Typically LCA involves the inventory of product and or service flows to include inputs, upstream factors of extraction, production, transportation and construction, use, and downstream factors of deconstruction and disposal. Global and regional impacts are then calculated based on energy consumption, waste generation, and a variety of other impact categories such as acidification, eutrophication, ozone depletion, and carbon emissions. Sometimes referred to as the cradle to grave approach, LCA allows the impacts from systems and materials to be weighed against each other (Keoleian and Scheuer 2002).

A key element that adds value to an LCA is transparent structure. An LCA promotes clarity of information and allows for greater comparability of products by documenting procedures, data sources, and boundaries and assumptions utilized. The general format for LCA, according to the International Organization for Standardization (ISO) 14040 conventions is described in Table 2-3 (ISO 2009).

“The notion of LCA has been generally accepted within the environmental research community as the only legitimate basis on which to compare alternative materials, services and components, and is therefore a logical basis on which to formulate building environmental assessment standards (Kleoleian and Scheuer 2002)." Researchers have attempted to use LCA to document the impacts of whole buildings, considering all building materials and operation, as opposed to just certain aspects of the building. Computer programs such as Athena, BEES, TRACI, and Envest incorporate LCA methods into tools for design and analysis of buildings (Kleoleian and Scheuer 2002).

Criticism of the LCA methodology focuses on conflicts between depth and applicability. Kleoleian and Scheuer cite for example in their research "Incorporating life cycle analysis in LEED" that a comprehensive LCA may not be easily interpreted, but if results are overly complex, underlying but significant details may be dismissed. As previously mentioned, the transparency of processes is important for the validity of an LCA, however this may dissuade many from participating because of concern over propriety information (Kleoleian and Scheuer 2002). Finally, there is an imbalance in current assessment criteria. Certain criteria, such as energy consumption and global warming potential are much easier to measure and their methods more established, however others such as ecotoxicity and resource depletion are complex to assess and their methodology is strongly contested. While both types of impacts are desirable in LCA, it is the ones that are accessible that are more often included. The specificity and rigor of LCA are required for accurate and meaningful assessment because of building complexities, but difficulties in conducting an LCA as well as the difficulties in interpreting and communicating the results prevent them from being utilized more often (Kleoleian and Scheuer 2002).

Design for Deconstruction and Disassembly (DfDD)

"It is undeniable that the current state of construction is wasteful and will be difficult to change (Kibert 2005)." The US EPA estimates that renovation and demolition make up 25-30% of the US annual waste generation (Guy 2002). In order to move from wasteful materials & resources practices to closed-loop materials behavior the green building movement will be required to embrace the concepts of deconstruction and design for disassembly. Deconstruction is the whole or partial disassembly of buildings to facilitate materials recycling and component reuse (Kibert 2005); Design for Deconstruction *(DfD)* is the conscious effort during the design phase to optimize the potential for deconstruction, as opposed to demolishing the building in full or partially, to allow the recovery of materials for recycling and components for reuse, as well as reduce long term waste generation (Kibert 2005). It is an emerging concept that borrows from the fields of design for disassembly, reuse, remanufacturing, and recycling in the consumer products industries (Guy 2002). According to Philip Crowther of the Queensland Technical University in Brisbane, Australia, there are 27 principles of DfD as applied to buildings and are listed in Table 2-4.

The problem existing for DfD is that the current state of deconstruction is limited by several factors. Cost and time represent interrelated factors, the first of these obstacles. The main opportunity factors for deconstruction are the prohibitive regulations and standards of building materials disposal as well as the value for recovered materials in environmental and economic terms. As such, the economic costs and benefits of recovered materials are the quality of materials, either high-quality reuse, economically recyclable, or hazardous materials and/or materials and systems that become obsolete or difficult to separate. Finally, buildings today are not designed for deconstruction (Guy

2002). Ultimately, closing materials loops in construction will necessitate the inclusion of product design and deconstruction together in a process that might be labeled Design for Deconstruction and Disassembly (DfDD) (Kibert 2005). Table 2-5 articulates the opportunities and constraints of deconstruction and a hierarchy for DfD is listed below (Guy 2002).

Hierarchy of Design for Deconstruction

1. **Design**
    - Minimize building depreciation from poor energy-use, climatic and materials performance by performance-based materials selection.
    - Substitute mechanical/gravity-based design for chemical-based design

2. **Construction**
    - Record as-built conditions
    - Create deconstruction plan based upon construction process
    - Record adaptations to building over its life

3. **Elements.** Design for modular and panelized elements that are readily fit into common dimensional standards and possible de-panelization
    - Principle DfD sub-goal- reuse

4. **Components.** Design for ease of separation from the next higher building level, i.e., elements
    - Reuse
    - Remanufacture

5. **Sub-components.** Design for separation from component level
    - Reuse
    - Remanufacture

6. **Materials.** Design for separation from sub-component level and as homogenous materials
    - Remanufacture
    - Recycle
    - Bio-degrade

Materials & Resources

Because of the large amounts of embodied energy in materials, building material selection is important to sustainable design and construction. Carbon emissions contributing to climate change through global warming and ozone depleting potential are the result of the extensive network of extracting, processing, and transporting of materials to the end user. Additionally, the process of creating building materials results in land and water pollution, destruction of natural habitats, and the depletion of natural resources. It is estimated that buildings consume 40% or three billion tons annually of the raw materials produced (Lenssen and Roodman). In recent years, products, services, and practices have attempted to reduce these negative impacts (Kleoleian and Scheuer). These environmentally conscious efforts, though widespread with increases in environmental awareness, are not standard. Such products and practices include the use of consumer and industrial bi-products and waste such as flyash in concrete, recycled plastic lumber, and engineered wood products to minimize both natural depletion of resources and end of life impacts. Furthermore, practices such as sustainable forestry, bamboo, and wheat straw board manufacturing involve environmentally friendly resource inputs from the beginning to accomplish sustainable material and resource objectives. Building reuse and salvaging efforts are additional strategies in creating longevity to existing materials and resources. Through differing methodologies, building rating systems require material and resource strategies for certification in an attempt to limit the negative impacts associated with building construction (Kleoleian and Scheuer 2002).

Building Assessment Systems

Building assessment standards and rating systems score or rate the effects of a building's design, construction, and operation. Among them are environmental impacts, resource consumption, and occupant health. They are generally created for the purpose of promoting high-performance green building and in some cases to increase market demand for sustainable construction. A superior building assessment rating should result in higher market value due to the building's lower operating costs and indoor environmental health (Kibert 2005). Table 2-6 outlines the building rating systems and standards to be evaluated in comparison to LEED.

The following section gives a brief history and description of the rating systems in Table 2-6. Aspects applicable to the research will be addressed to include materials and resources credits, life cycle assessment and resource conservation through design.

United States Green Building Council

"The sustainable development movement has been evolving worldwide for almost two decades, causing significant changes in building delivery systems in a relatively short period of time (Kibert 2005)." Over the past decade, however, the movement has seen exponential growth as evident by the rapid increase in membership of the United States Green Building Council (USGBC) and the arguable success of its suite of building rating systems known as Leadership in Energy and Environmental Design (LEED). In 2001 the membership of the USGBC was 1,137 with 527 LEED accredited professionals and five certified projects (White Paper 2003). As of January 2009, the membership was 18,086 with over 100,000 LEED AP's, over 2,100 certified projects under LEED for New Construction (LEED-NC) and over 17,000 projects registered under LEED-NC (USGBC 2009). These statistics are evidence of the success and rigidity of the sustainability movement within the United States.

In 1993 the USGBC was founded as a non profit organization made up of government, industry, and academia intended on reshaping the built environment (Kibert 2005). Between 1993 and 1998, a USGBC task force worked to create a rating system that would evaluate a buildings performance relative to environmental impacts and resource efficiency. According to Kibert, “LEED removed ambiguity in the loosely interpreted concepts associated with green building and sustainability (Kibert 2005).” In both the private and public sectors, LEED has had rapid uptake and has significantly impacted the construction industry within the United States. “The most likely reason for such wide acceptance has been the result of its authors’ focus on fashioning LEED as a market-driven, consensus- based rating system that facilitates creating buildings with higher market value (Kibert 2005).”

Since its inception in 1998 as a pilot project program known as LEED version 1.0, the USGBC has gone through several major revisions to the LEED-NC system to include versions 2.0, 2.1, 2.2, and most recently version 3.0. Each revision has brought about major criticism to both the standard and the USGBC. Schendler and Udall argue in their article “LEED Is Broken- Let’s Fix It” that LEED (1) is too costly for certification, (2) facilitates point mongering, (3) energy modeling in LEED is too complicated; 4) there are too few credits for saving energy, (5) there is excessive bureaucracy, (6) there are overblown claims of green building benefits to include worker productivity, and (7) the USGBC is unreceptive to constructive criticism (Schendler and Udall 2005). Additionally, the North American Coalition on Green Building has argued that the government should not rely solely on the USGBC and LEED to ensure building efficiency. They believe that green standards should be developed by accredited standards organizations and that efforts should be taken to ensure transparency and opportunity for significant input from organizations affected by such standards (NACGB 2009). The American National Standards Institute (ANSI) coordinates the standards process development in the United States and is currently working with the Green Building Initiative on the proposed green building standard 01-2008P based on Green Globes, as well as a joint effort with ASHRAE, IESNA, and the USGBC on standard 189.1p based on LEED. These standards will provide a baseline for minimum green building standards into mainstream building practices (ASHRAE 2006).

According to the USGBC, LEED encourages and accelerates global adoption of sustainable green building and development practices through the creation and implementation of universally understood and accepted tools and performance criteria (USGBC). The LEED-NC rating system is designed to guide and distinguish high-performance commercial and institutional projects, including office buildings, high-rise residential buildings, government buildings, recreational facilities, manufacturing plants and laboratories (USGBC). LEED version 3 was launched in April of 2009 and incorporates a revised system known as LEED 2009. The standard rates a buildings performance in the following categories:

- Site Selection
- Water Efficiency
- Energy & Atmosphere
- Materials & Resources
- Indoor Environmental Quality
- Innovation in Design
- Regional Priority

The three major differences of the current version to previous versions are the harmonization of suites (e.g., New Construction (NC), Existing Building: Operations & Maintenance (EB), Core & Shell (CS), Schools, Retail, and Healthcare, and Commercial Interiors (CI)), revised credit weightings, and regionalization (i.e., regional priority credits.)

Harmonization. Drawing on all common denominators, all credits and prerequisites from LEED commercial and institutional rating systems were aligned and consolidated so that all credits and prerequisites are consistent among the suites of LEED. The necessary precedent-setting and clarifying information from Credit Interpretation Rulings (CIRs) were incorporated into the rating systems (USGBC).

Regionalization. Through USGBC's regional councils, chapters, and affiliates, regionally specific environmental issues were identified. For a project's specific location, six LEED credits have been prioritized because they address the specific environmental issues.

Credit weightings. According to the USGBC, the largest advancement to the LEED rating system has come from credit weightings formulated on each credit's ability to affect different aspects of environmental and health concerns. With revised credit weightings, LEED now awards more points for strategies that will have greater positive impacts on energy efficiency and CO2 reductions. According to Penny Bonda in her article "The New LEED: All About Weightings", the revised credit weightings are "the result of the USGBC recognizing that all building criteria are not of equal importance and that the revisions represent scientifically grounded reevaluations that place an increased emphasis on carbon emissions and energy use reduction (Murphy 2009)."

Each credit was evaluated against a list of 13 environmental impact categories, including climate change, indoor environmental quality, resource depletion and water intake, etc. The impact categories were prioritized, and credits were assigned a value based on how they contributed to mitigating each impact. The results showed each credit's portion of the overall system, giving the most value to credits that have the highest potential for making the biggest change to reducing environmental impacts. The credits have not changed from the previous version; they simply are worth different amounts. As a result, LEED 2009 operates on a 100-point scale with bonus credits for innovation in design and regional priority credits (USGBC 2009). Specific examples cited by the USGBC include for credit weightings include:

Sustainable Sites c4.1: The proximity of a building to public transportation allows for building occupants to utilize alternative transportation methods which have impacts associated with fossil fuel depletion, land use, acidification, ozone depletion, smog formation, ecotoxicity and overall human health effects caused by reducing single-occupant vehicle use. It also affects the building's carbon footprint, a significant environmental component associated with transportation to and from the building. As a result LEED 2009 has increased point values for this credit to reflect such theory (USGBC 2009).

Water Efficiency c1: Water use reduction associated with irrigation outside the building and fixture/fittings use inside the building has impacts on resource depletion and water shortages leading to agricultural, human, plant, and animal effects. While the impacts of these credits were primarily in water use, the benefits of water reduction are heavily emphasized in LEED 2009 (USGBC 2009).

Energy & Atmosphere c2: The utilization of renewable energy for a building's energy needs reduces the dependency on less environmentally friendly energy sources, causing a variety of impacts on the environment and human health. Using renewable energy impacts a building's carbon footprint, contribution to fossil fuel depletion, ozone depletion and rate of particulates, which may lead to chronic and acute respiratory symptoms (USGBC 2009).

The USGBC notes the changes to the weightings result in incremental change to the system as a whole, but that existing credits maintain a substantial minimum weighting. Table 2-7 shows the whole system weighting comparisons of v2.2 to v3.

Furthermore, the "new impact driven, paradigm changes are superimposed on the existing skeleton and change the relative emphasis of the system but do not constitute a wholesale reinvention of the weightings (USGBC 2009)." The LEED weighting system intends to provide a transparent and reproducible approach to assign weights to credits. "The system is a flexible, decision support environment that allows decision makers with explicit control over the integration of analytical results, policies, and values (USGBC 2009)." Weighting for each LEED 2009 system are documented with a self-contained Microsoft excel workbook. Each workbook contains all calculations and rules used to assign weights to individual LEED credits. The workbook also serves as a decision support tool to evaluate the consequences of alternative scenarios on credits or the rating system as a whole (USGBC 2009)." The design constraints of the weighting process are as follows:

1. The existing credits remain the same.
2. All credits receive a minimum score of 1.

3. Credits are positive whole numbers (no fractional values or negative numbers).

4. Credits have one set of static weights regardless of location or potential connections.

The LEED 2009 rating system explicitly integrates building impacts with the existing structure of LEED to include six components:

- a building prototype
- impact assessment categories
- credit groups
- transportation control
- credit adjustments
- point reallocation

These components work together to provide a representation of building impacts and use this information to assign points to individual credits. Each component provides an opportunity to change the ultimate weight of a credit. The most important single factor is the selection of a building prototype. This decision has the greatest potential influence and is subject to the greatest range of potential conditions (i.e.,, observed variance in key parameters). This is followed closely by the weights applied to impact assessment categories (i.e.,TRACI weights). The last three components essentially provide opportunities for fine tuning (USGBC). Table 2-8 describes the weighting process.

The LEED 2009 weighting system brings together a number of informational sources such as the US EPA's Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI) (USEPA). Models and statistical information is used to estimate building impacts and associate impacts with individual TRACI categories. Specific information sources used in individual calculation are documented throughout each LEED workbook. The association between impact categories and information sources is shown in Table 2-9.

The LEED 2009 weighting system is a decision support tool. It provides a framework for integrating the structure of the existing rating system with an impact-oriented weighting system. The system itself does not provide weights as an output. Rather, it provides a framework for evaluating the interlocking set of issues that contribute to weights and ultimately changes the LEED scorecard (USGBC 2009).

LEED 2009 materials & resources. The intent of the materials & resources (MR) category of LEED is to promote building design choices that protect natural resources, and minimize the impacts of the construction process (Kleoleian and Scheuer 2002). According to the USGBC, this credit category encourages the selection of sustainably grown, harvested, produced and transported products and materials. It promotes the reduction of waste as well as reuse and recycling, and it takes into account the reduction of waste at a product's source. Table 2-10 illustrates the seven credits and their relative emphasis on the MR category as well as the rating system as a whole.

ASHRAE Standard 189.1p

In 2006 the USGBC, the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) and the Illuminating Engineering Society of North America (IESNA) announced that the three organizations would co-sponsor the development of a new ASHRAE/USGBC/IESNA minimum standard for high performance green building (ASHRAE 2006).

The proposed standard for the design of high-performance green buildings except low-rise residential buildings provides minimum requirements for the design of sustainable buildings to balance environmental responsibility, resource efficiency, occupant comfort and well-being, and community sensitivity. Using the USGBC's LEED rating system, standard 189.1p provides a baseline that will drive green building into mainstream building practices (ASHRAE 2006).

Currently in its fourth public commenting period until November 2009, the proposed standard will apply to new commercial buildings and major renovation projects, addressing sustainable sites, water use efficiency, energy efficiency, a building's impact on the atmosphere, materials and resources, and indoor environmental quality (ASHRAE 2006).

Standard 189.1p will be an ANSI-accredited standard that can be incorporated into building code. It is intended that the standard will eventually become a prerequisite under LEED. The criteria for the materials and resources section of the standard is very similar to LEED only that building reuse, and materials reuse are not included in the requirements. However, Life Cycle Assessment is a performance path of which the project may choose to pursue as opposed to a prescriptive path of recycled content materials, regional materials, and bio-based materials (ASHRAE 2006).

Green Building Initiative

The Green Building Initiative (GBI) is a not for profit organization whose mission is to accelerate the adoption of building practices that result in energy-efficient, healthier and environmentally sustainable buildings by promoting credible and practical green building approaches for residential and commercial construction (GBI 2009). In 2004, GBI obtained the rights to distribute Green Globes in the US market after originally being modeled after the United Kingdom's BREEAM rating system in Canada. Furthermore, in 2005 ANSI established GBI as a standards developer and began the process of establishing Green Globes as an official ANSI standard (Ghatee 2007).

According to the GBI, the green globes is “a revolutionary green building guidance and assessment program that offers an effective, practical, and affordable way to advance the overall environmental performance and sustainability of commercial buildings (GBI 2009).” Essential elements of the system include:

- comprehensive environmental assessment protocol
- software tools that speed and simplify online assessment
- best practices guidance for green construction and operations
- qualified assessors with green building expertise
- rating/certification system

Based on its recognized and proven assessment protocol, using the Green Globes software tools and ratings/certification system ensures that environmental impacts are comprehensively assessed on a 1,000 point scale in multiple categories to include:

- Energy (360 points)
- Indoor Environment (150 points)
- Site (115 points)
- Water (100 points)
- Resources (100 points)
- Emissions (75 points)
- Project/Environment Management (50)

After achieving a threshold of at least 35% of the total number of 1,000 points, new and existing commercial buildings can be certified for their environmental achievements and sustainability by pursuing Green Globes certification that assigns a rating of one to four globes. Highly qualified third-party assessors (with expertise in green building design, engineering, construction and facility operations) conveniently interface with project teams and building owners during the third-party assessment process by reviewing building documentation and conducting on-site walk throughs. Green Globes rating certification is suitable and practically attainable for a wide range of commercial buildings, and enables building owners to credibly market their environmental responsibility to shareholders, tenants, and the broader community.

The current version of Green Globes includes education credits encouraging design teams to use LCA as part of their materials decision making process. But with the new LCA tool commissioned by the GBI, design teams are now able to compare alternate design scenarios and building assembly choices through use of a free, easy to navigate software tool developed by the ATHENA Institute. The software tool provides LCA results for hundreds of common building assemblies in low- and high-rise categories including exterior walls, roofs, intermediate floors, interior walls, windows, windows, and columns and beams. The ATHENA Impact Estimator for Buildings software was used to generate the results embedded in the tool. The GBI is also in the development with ANSI of a green building standard based on the Green Globes rating system. The MR credits in both systems are extremely similar, however quantifying the requirements and relative percentage emphasis is much easier using the ANSI standard. Table 2-11 illustrates the resources and materials criteria for the proposed standard.

Design for disassembly in ANSI standard 01-2008P. As shown in Table 2-11, the ANSI standard 01-2008P awards points under section 10.6: Resource Conservation through Design. Under this credit, points are awarded for design strategies that use materials and raw materials efficiently as compared to typical construction, building assemblies that perform multiple functions, and building design plans that facilitate demounting or disassembly of materials without substantial damage to the materials or their surroundings (GBI 2009).

German Sustainable Building Council (DGNB)

The task of the German Sustainable Building Council is to point out and advance paths and solutions for sustainable building (DGNB 2008). This includes the planning of buildings, but also their construction and operation. The DGNB considers itself to be the central German organization for exchange of knowledge, professional training, and for a raising public awareness for this future-oriented part of the building sector. The focus of the DGNB is on awarding the certification for sustainable building. The first time the Sustainable Building Certification was awarded was at the BAU 2009 in Munich. Initially, it was awarded for the system variation “New Construction Office and Administration, Version 2008” (DGNB 2008).

In version 2008, which emerged from the pilot phase of the certification system, the sustainability of office and administration buildings is evaluated based on six topics covering 49 criteria. The system is a transparent and comprehensible rating system that was developed based on real-world circumstances (DGNB 2008). It defines the quality of buildings in a comprehensive way, and enables an auditor to conduct an evaluation systematically and independently. The basis of the evaluation, which was developed with a wide consensus, includes topics of:

- Ecological Quality
- Economical Quality
- Socio-cultural and Functional Quality
- Technical Quality
- Quality of the Process
- Quality of the Location

The criteria are weighted differently depending on the building type to be evaluated (i.e., each version of the system based on building type has its own evaluation matrix). For each criterion, measurable target values are defined, a maximum of 10 points can be assigned, and the measuring methods for each criterion are clearly defined. At the same time, each criterion has a weighting factor from 0-3: it can flow threefold into the evaluation of its respective topic. Each criteria flows into the overall result in a clearly differentiated way. A software-supported computation displays the building's performance: by reaching a defined degree of performance, it is assigned the bronze, silver, or gold award. Additionally, grades are given for the total performance of the building as well as for individual topics.

The evaluation is measured by degree of compliance and includes:

- 50% for Bronze
- 65% for Silver
- 89% for Gold

A unique aspect of the DGNB certificate is the Praxis-oriented continuing development of the system. On this basis, the German Sustainable Building certificate can be adapted, in a practicable way, to the individual requirement of different building types. Similarly, it can be adapted to regional requirements or social developments, for example, to the increasing importance for individual criteria like indoor air quality or CO2 emissions of a building. The strength of the system is also based on the involvement, from the beginning, of interested parties during the development of new variations. "A supplementary commenting procedure ensures that the requirements of the construction and real estate sector are systematically queried and included into the system (DGNB 2009)." Table 2-12 illustrates the criterion and relative importance of the resources and materials section of the DGNB Certificate.

Design for disassembly/deconstruction in the DGNB certificate. The goal of increasing the ease of deconstruction, recycling, and dismantling is the avoidance of waste, in particular by reducing its amount and hazard. 50% of the waste in Germany can be assigned to the building sector (DGNB 2009). The amount of accumulated waste is to be reduced, and is to be led into the recycling system. Due to the comparatively long expected useful lifetime, many of the materials that are used today will not accumulate as deconstruction material or potential waste until 50 or 100 years after construction. These materials can serve as important resources for future construction materials. The ability to recapture homogenous deconstruction materials and extract high-grade recycling materials is very important for the evaluation of this criterion. The methodology for DGNB criterion 42 includes:

- building services
- non-structural (de)construction parts
- non-bearing carcass structure
- bearing carcass structure

For each group, the following topics are considered:

1. effort of dismantling-divided into 5 dismantling stages
2. effort of separation-divided into 5 stages
3. Are there hazardous building materials or materials that need to be declared that require special disposal?
4. Can these materials be easily separated and is a separated disposal possible?
5. Can a verifiable recycling-disposal concept be attached to the request for certification?
6. What is the potential further path of the vast majority (mass) of the construction components?

International Initiative for a Sustainable Built Environment (iiSBE)

The iiSBE is an international non-profit organization whose overall aim is to actively facilitate and promote the adoption of policies, methods and tools to accelerate the movement towards a global sustainable built environment (iiSBE 2009). The iiSBE has an international Board of Directors from almost every continent and has a small Secretariat located in Ottawa, Canada. The specific objectives include 1) mapping current activities and establishing a forum for information exchange on SBE initiatives, so that gaps and overlaps may be reduced and common standards established; 2) to increase awareness of existing SBE initiatives and issues amongst the international buildings and construction community; and 3) to take action on fields not covered by existing organizations and networks. The iiSBE is best known for the continuing development of their building performance assessment system formerly known as GBTool and now known as SBTool. This is a flexible framework operating on Excel that can be configured to suit almost any local condition or building type (iiSBE 2009).

Green Building Challenge and SBTool. Through the work of more than 20 countries, the iiSBE has developed the SBTool mainly through the Green Building Challenge (GBC) process that extended from 1995 to 2005. National teams participated in the development of the method and tested it on case study buildings in their own countries, then presenting the results at international SB conferences. SBTool reflects the continued work of the iiSBE and is a totally restructured version reflecting the inclusion of a range of socio-economic variables (iiSBE 2009).

The SBTool allows countries to design their own locally relevant rating systems, and is designed to include consideration of regional conditions and values, in local languages, but the calibration to local conditions does not destroy the value of a common structure and terminology. According to the iiSBE the tool produces both relative and absolute results making it a very useful international benchmarking tool, one that provides signals to local industry on the state of performance in the region, while also providing absolute data for international comparisons (iiSBE 2009). The system is a rating framework or toolbox that only becomes a rating tool when a third party calibrates the system to the specific region by defining scope and setting weights, context, and performance benchmarks.

The system contains three levels of parameters that nest within each other; Issues, Categories and Criteria; the criteria are scored according to the following scale:

- -1 = deficient
- 0 = minimum acceptable performance
- +3 = good practice
- +5 = best practice

Criteria scores are weighted, Category scores are the total of weighted Criteria scores, and Issue scores are the total of weighted Category scores. Table 2-13 reflects the points within SBTool the materials & resources category.

CHAPTER 3
METHODOLOGY

Research was conducted to analyze the strategies and methodology to the materials and resources category of LEED 2009 in comparison to the building assessment standards and rating systems: ANSI standard 01-2008P, the German Sustainability certificate, SBTool, and ASHRAE 189.1p.

A comparison of LEED to these standards was conducted to show credit weighting within the system, credit achievement levels, and meritorious credits, strategies, and goals not recognized by LEED. Through comparison matrices, each credit within LEED is evaluated and compared against the other systems. Based upon a collection of best practices, recommendations are made. The life cycle assessment approach to credit weightings of LEED 2009 was evaluated to an LCA method for individual projects that use similar environmental building impacts. Additionally, research was conducted on resource conservation through design to include Design for Deconstruction/Disassembly and design for multi-functional assemblies to establish a structure for credit within a revised MR framework. Finally, credits not currently included in LEED that may result in significant impacts to the goals of the M&R category are considered.

The collective research effort facilitates the development of a revised framework for materials and resource credits to be recommended to the LEED MR Technical Advisory Group (TAG). This shall provide continued improvement and environmental responsibility relative to assessment systems and standards worldwide.

CHAPTER 4
RESULTS AND ANALYSIS

This chapter is divided into two major sections: the comparisons of building assessment standards to LEED 2009 and suggested modifications to the LEED rating system. Within this chapter, the LEED LCA approach to credit weightings is evaluated relative to an LCA of individual projects. Finally, resource conservation through design and other materials & resources elements of the standards are analyzed resulting in a revised framework for LEED M&R.

Materials & Resources Comparisons

This section compares the LEED 2009 rating systems' materials and resources credits to that of SBTool, the DGNB certificate, ANSI standard 01-2008P and ASHRAE 189.1p. Tables 4-1 through 4-4 compare LEED to the other rating systems' achievement criteria as well as credit weighting percentage relative to the whole system. The details of the analysis and results by criterion are listed below.

Collection of Recyclables

The collection of recyclables is a consensus credit/prerequisite among the rating systems that attempts to reduce the waste generation of building occupants that is hauled to landfills. It involves setting aside area based on the size of the building for the storage and collection of recyclables such as paper, cardboard, glass, plastics, and metals. Additionally, ASHRAE 189.1p based on LEED requires for residential buildings that storage area be set for reusable goods for collection by charitable organizations, as well as storage for fluorescent, HID lamps, and ballasts by all buildings.

Building Reuse

The building reuse-structural criterion among the standards has the same intent of attempting to reuse the existing building stock as opposed to the negative environmental impacts of new construction. The achievement levels, based on square footage, are fairly comparable. However, LEED 2009 mandates the weighted criterion regardless of new construction as opposed to the proposed ANSI standard 01-2008P and the SBTool that allow for the criterion to be non-applicable, given existing building conditions. This allows for increased emphasis on credits pertinent to the project such as recycled content or design for disassembly.

Construction Waste Management

The intent of this credit is to reduce the generation of waste disposal and divert to recycling programs. The DGNB rating system and ANSI standard are of equal importance; however, LEED places over twice the weighting on this credit as a result of system design rounding criteria. The SBTool is unique in that weightings may be adjusted specific to individual projects and locations. The variable weightings allow for increased emphasis on this credit, for example, if materials reuse is not factored into the rating tool, the emphasis for construction waste management may be doubled. The achievement levels are unknown for the SBTool and DGNB but ANSI 01-2008 and LEED are comparable at 50% minimum and 75% maximum point potential.

ASHRAE 189.1p allows for the inclusion of packaging materials to be sent to the manufacturer or shipper for reuse, an inclusion that is not recognized by any other systems. The ASHRAE standard also incorporates a total waste criterion in which a project with less than 5% of existing building, structure, or hardscape must not generate total waste of 42 cubic yards or 12,000 lbs per 10,000 square feet of building area. This criterion applies to all waste whether landfilled, incinerated, diverted or otherwise disposed of.

Materials Reuse

This credit intends to reduce the extraction of virgin resources by utilizing salvaged and/or refurbished materials on construction projects. The standards exhibit similar achievement level percentages based on materials costs. It is important to note that mechanical, electrical, and plumbing components, as well as specialty equipment such as elevators are not included in these calculations. The weighted percentage of LEED's materials reuse is over twice that of ANSI. The DGNB and ASHRAE do not have a comparable credit and the SBTool is project specific allowing for inclusion if the project team so chooses to pursue.

Recycled Content

The intent of this credit is to reduce the extraction of virgin resources by using post-consumer and pre-consumer recycled content. Examples of such include recycled steel and flyash in concrete. The standards exhibit similar achievement level percentages based on total materials costs, but it is important to note that only the percentage of recycle content (by weight) relative to the whole assembly may contribute to this credit. If materials costs are unknown than a default value of 45% of the total project may be used. The weighted percentage of LEED's recycled content credit is over twice the amounts of the other standards. The DGNB does not have a comparable credit.

Regional Materials

The regional materials criteria of these various standards serves to promote the demand for building materials and products that are extracted and manufactured within the region, thereby supporting the use of indigenous resources and reducing the environmental impacts resulting from transportation. The SBTool does not define a specific distance, as a result of their variable location adjustments and 3rd party assessment, however, LEED and the ANSI standards support regional materials extracted, processed, and manufactured with 500 miles of the project based on total costs. If components of the assembly do not meet this criteria, they are not to be excluded (by weight) multiplied by the cost of the assembly. These two standards are similar in achievement levels, while SBTool demands more than three times the percentage by weight of materials as LEED and ANSI. The DGNB does not have a comparable credit.

Rapidly Renewable Materials

The rapidly renewable resources credit of LEED is the only such credit by definition compared to the other standards. The intent is to reduce the use and depletion of finite raw materials and long-cycle renewable materials by replacing them with rapidly renewable materials. Under the assessment methods of ANSI and SBTool, all certified bio-based materials to include long-rotation (i.e., wood products) are accepted. The achievement levels are five to seven times more stringent than LEED's 2.5% based on material costs; however, this reflects the range of acceptance for bio-based materials. According to an LCA study by Greg Norris of Sylvatico, an LCA consulting firm in North Berwick, Maine, there is no significant evidence to justify rewarding rapidly renewable resources (i.e., cork, linoleum, wheatboard) over wood products. The weighting of this criterion throughout the different standards is relatively proportional.

Certified Wood

The certified wood criterion of building assessment systems intends to encourage environmentally responsible forestry management. The weighted percentages of LEED are twice that of ANSI but less than the overall weighting of the DGNB. Each rating system demands approximately 50% certified wood for best practices achievement with the exception of ASHRAE that specifies 60%. LEED is the only standard of which the Forestry Stewardship Council's (FSC) FSC-STD-40-004 V2-0 chain-of-custody is the only authorized certificate for credit award. Among the accepted organizations of this criteria for the DGNB and ANSI standard are forestry stewardship programs of: Program for Endorsement of Forest Certification Schemes (PEFC) Council Technical Document-October 5, 2007, American Tree Farm System (ATFS) 2004-2008 AFF Standard, Canadian Standards Association Z809 Sustainable Forest Management Requirements and Guidance (SFM) 2002, and the Sustainable Forestry Initiative Program (SFI) 2005-2009 Sustainable Forestry Standard (SFIS). Additionally, ASHRAE 189.1p recognizes sources certified through a forest certification system with principles, criteria, and standards developed using ISO/IEC Guide 59, or the WTO Technical Barriers to Trade.

Resource Conservation Through Design

Resource conservation through design or Design for Disassembly and Deconstruction (DfDD) is a criterion opportunity in the proposed ANSI standard, the DGNB Certificate, and the SBTool. The weighted average over the whole system for this credit is approximately 2.0%. The intent of this rating criterion is to facilitate design and planning of building assemblies so that at the end of their useful life (50-100 years) they can be disassembled or deconstructed in a safe and efficient manner to provide valuable resources and materials to future industry, thus reducing waste generation and future demand on scarce virgin resources. Although, these rating systems call out DfDD, only the DGNB gives methodology to the achievement of this criterion. This methodology is listed in Chapter 2. It is important to note that neither LEED nor ASHRAE 189.1p have a DfDD or resource conservation through design credit.

Life Cycle Assessment

The environmental building impacts LCA method of LEED has been described in great detail in Chapter 2 of this research. Each of the other building rating systems calls for an LCA of building impacts similar to those of TRACI. The DGNB requires LCA methods using ISO 14040, SBTool requires acceptable LCA approaches or use of their “crude” embodied energy excel spreadsheet, the ANSI standard requires the use of the Green Globes LCA calculator for building assemblies that covers criteria previously mentioned in chapter 2, and ASHRAE 189 requires an LCA performance path in lieu of criterion 9.4.1-3 to include recycled content, regional materials, and bio-based materials. Each of these four rating systems/standards approach LCA on an individual project basis incorporating material use alternatives as an approach to building delivery as opposed to LEED’s methodology for weighted criteria based on a two-story prototype office building.

Other Criteria

The minimum use of finish materials and virgin materials are synergistic credits through SBTool whose intent are to limit the extraction of virgin materials and the effects of processing, manufacturing, and transporting of finish materials. The achievement criteria is in percentage of floor, wall, or ceiling area in which structural elements are left exposed or are of non-virgin resource material. Additionally, credit may be awarded for the use of durable finish materials as specified by ISO 15686-1 Building and Construction Assets Service Life Planning: General Principles or the Canadian Standards Association CSA 478-95 “Guideline on Durability in Buildings”. The intent of this credit is to prolong the useful life of the building to reduce the need of renovation, an activity that has proven to generate a significant amount of waste each year.

Conclusions

This section provides an analysis of the revised MR category framework for LEED-NC. The recommendations are based upon best practices among the standards and rating systems, collectively. In other words, no system is better at evaluating the existing categories than another because one may place more emphasis on recycled content, where as another may place more emphasis on materials reuse. Furthermore, as a result of the uncertainty of strategies and methodologies such as resource conservation through design and life cycle assessment, no assumptions can be made as to the superiority of one systems’ weighting of such categories. The MR framework consisting of seven credits and their points, intent, requirements, suggested submittals, and potential technologies and strategies is listed in the appendix.

Materials & Resources prerequisite 1: Storage & Collection of Recyclables. With the excessive amount of waste generation by building occupants, it is environmentally responsible to make this criterion a requirement for certification. LEED, along with ASHRAE 189.1p will continue to facilitate the reduction of waste generation of cardboard, plastics, glass, paper, metals and organic wastes during facility operations. The recommendations include areas for the collection and storage of fluorescent, HID Lamps, and ballasts for proper disposal according to local and state hazardous materials guidelines.

Material & Resources credit 1.1-1.2: Building Reuse. The USGBC has great intentions for these credits. The most significant potential for green building exists with the reuse of existing structures and interior elements to limit the environmental impacts of new construction. However, owners will continue to do new construction until there is a paradigm shift to major renovation in the building industry. Perhaps the USGBC could facilitate such a movement by incorporating significant bonus credit award to projects registered as major renovation. Each building assessment system recognizes the potential for the reuse of existing structures; however, LEED is the only system that was studied in which the points remain a factor if the project is ineligible to receive credit.

In order to achieve LEED certification, a minimum of 40 points is required. This methodology of certification based on achieving a minimum point level is misrepresentative of new construction assessment. Throughout the LEED scorecard there are credits that could be non-applicable (e.g., building reuse, brownfield redevelopment) therefore making a potential difference to certification levels. In other assessment systems, non-applicable credits are not factored into the total points and certification is based upon a minimum percentage threshold (i.e., 35% of total points for basic certification).

It is recommended that the USGBC change their point methodology to reflect a non-applicable, percentage based on total points strategy. Projects registered as major renovation would have the option of attaining the various achievement levels of this credit as bonus points to the LEED scorecard, representing a potential bonus of up to

9%. This methodology could encourage project owners to consider, more heavily, the use of existing building stock in this country. The limitation to this theory is that existing building projects may take advantage of the significant bonus credit and be less likely to achieve silver, gold, or platinum status. To combat this limitation, it is recommended that projects achieve minimum certification to be eligible for the bonus points in building reuse.

Additional revisions to these credits include more achievement levels based upon percentage of area reused, and weightings over twice the previously levels. Additions to the building may now be up to four times the size of the existing structure for credit applicability to encourage reuse of interior elements.

Materials & Resources credit 2: Construction Waste Management. The intent of this credit is extremely effective and is comparable by achievement levels as the other standards researched (i.e., 50%-75% waste diversion from landfills). However, the weighting of this credit in LEED 2009 is 2% of the whole system as opposed to approximately 0.75% on average of the other systems. According to the White Paper on Sustainability: A Report on the Green Building Movement in 2003, 79% of projects achieved the 50% mark for this credit (a full listing of the most achieved and least achieved credits may be found in Appendix C). As a result of increase landfill tipping fees over the past six years, it would not be surprising to learn that this percentage is higher today. Furthermore, as a result of these high tipping fees, asphalt and concrete, both significant contributors to the total weight/volume of construction waste on projects, are recycled for the simple economic aspects of waste disposal.

This collection of evidence draws the conclusion that LEED 2009's weightings for construction waste management are too high and must be brought down to comparable levels. It is recommended that the USGBC decrease the overall emphasis of this credit to a percentage less than is previously accounted for and require the 50% achievement level. This would free up a percentage available for environmental innovation of concepts and strategies resulting in positive impacts to sustainable design and construction. Additionally, a total waste limitation identical to ASHRAE 189.1p has been included to further facilitate the goals and strategies of this credit. A final note to this credit relates to ASHRAE 189.1p in that packaging materials returned to the manufacturer, shipper, or other source that will reuse the materials for future delivery are included in the calculations. This recent inclusion to the 4th public commenting period for this standard is environmentally sensitive in that the cost-benefits ratio for this strategy relative to the transportation impacts is unknown. It is recommended that if the standard is to become a prerequisite to LEED, according to an ASHRAE press release in 2006, this inclusion needs to be re-evaluated.

Materials & Resources credit 3: Materials Reuse. According to the White Paper on Sustainability 2003, only 1 of 38 projects was awarded for this credit. The intent of this credit has merit, however, the feasibility of reusing building components, products, and furnishings is extremely low. This credit accounts for 2% of a certification under LEED, over two and half times that of SBTool or ANSI 01-2008. It is important to note the exclusion of this credit in ASHRAE 189.1p. It is recommended that this credit be worth only one point and that the points freed up from the may become a part of an innovative strategy for incorporating resource conservation through design into LEED.

Materials & Resources credit 4: Recycled Content. According to the White Paper on Sustainability 2003, 33 of 38 projects were awarded the 10% achievement level for this credit. The achievement levels are comparable across each building assessment standard, however, the weightings of which are not. LEED emphasizes this credit with over twice the weighting as ANSI 01-2008P and SBTool. Furthermore, with advances in flyash, and other pre-consumer cementitious recycled content concrete, as well as 87% of LEED projects achieving this credit, it is recommended that the USGBC require 10% achievement levels of this credit to incorporate higher levels of standard. The inclusion of MEP is recommended according to ASHRAE 189.1p, as well as the inclusion of recyclable materials criterion.

The current credit calls for building materials with recycled content, however, if recyclable building materials were specified, the environmental benefits recognized for future generations would be significantly higher than current practices. The inclusion of recyclable materials with the given requirements and weighting will facilitate further development of the goals and strategies of this credit.

Materials & Resources credit 5: Regional Materials. This credit seems to have the most consensus among the rating systems studied. Between LEED and ANSI, the weighting of this category is comparable in each of the standards, with similar achievement levels at 10%, however, ASHRAE 189.1p specifies 15%, perhaps in recognition of the need for higher standard. SBTool does not have a specific mileage amount of which the materials must be extracted, processed, and manufactured from. However, it does require up to 90% of the cost of materials for best practices award. Based upon third party evaluation, the mileage and amount of materials are crossreferenced with location, and the award is given. This credit may be flawed because this certainly encourages the use of regional materials, however, if project teams do not accept products from distant lands, how are they to be sure they are getting the very best value for the materials and products that are specified?

According to the White Paper on Sustainability 2003, the first achievement level of this credit was awarded to 38 of 38 projects. This overwhelming statistic could suggest that regardless of credit award, projects will purchase regional materials for simple economic reasons. The recommended changes include requiring 15% achievement in accordance with ASHRAE 189.1p.

Materials & Resources credit 6: Sustainable Materials Selection. LEED is the only standard researched to specify short-rotation (10 years or less) bio-based resources. According to the White Paper on Sustainability 2003, only 2 of 38 projects received award for this credit and as previously mentioned LCA studies by Greg Norris have suggested that there is no significant benefit to the use of rapidly renewable resources as opposed to wood products. This has been a contentious credit for several years and it is recommended to the USGBC that they include both resources for credit within LEED. The weightings are of equal importance to other standards and achievement levels shall remain the same. Bio-based materials shall comply with the minimum bio-based contents of the USDA’s Designation of Bio-based Items for Federal Procurement, contain the USDA Certified Bio-based Product label, or be composed of solid wood, engineered wood, bamboo, wool, cotton, cork, agricultural fibers, or other bio-based materials with at least 50% bio-based content. Additional revisions to this credit include the mergence of MRc7 Certified Wood as a result of its synergistic nature with bio-based resources selection.

As previously mentioned, the USGBC only accepts a chain of custody verification through the Forest Stewardship Council while other standards accept verification through a number of different sources. This has been another credit of considerable contention and as a result of similar practices and standards, it is recommended that the USGBC accept any certified wood content documentation by sources certified through a forest certification system with principles, criteria, and standards developed using ISO/IEC Guide 59, or the WTO Technical Barriers to Trade. The weightings shall remain the same, however, achievement levels will increase to 60% in accordance with ASHRAE 189.1p. Finally, LCA will be incorporated into this credit due to the relative pertinence of sustainable materials selection.

The USGBC recognizes the uncertainty and limitations to the LCA approach. Calculations to estimate impacts are based on simple scalars such as energy use per square foot, emissions per gallon, therm, or kilowatt, etc. These simple calculations inherit the limitation of their data sources such as the Department of Energy’s Commercial Building Energy Consumption Survey (CBECS) in which it represents the population of buildings LEED targets. Errors or uncertainties in CBECS influence the degree to which the median prototype used in the workbook represents the national average. More importantly, building scenario choices has a direct and significant impact on the weighting system. This is certainly the case because the new system attempts to integrate the existing structure with explicit consideration for building impacts: when building impacts change, the importance of credits change as well as their relative weight within the system. The workbooks used by the USGBC are designed to illustrate the consequences of the range of conditions found across the United States. However, the rating system ultimately requires selecting one prototype condition and using it as the basis for weights.

This methodology does not represent a significantly responsible approach to environmental building impacts in comparison to other standards and rating systems. An LCA approach to individual projects has been included in the revisions to LEED MR in accordance to ASHRAE 189.1p. The difference is that four impact categories must show a 5% improvement over another building alternative as opposed to only two impacts. It is assumed that LEED should raise the performance bar relative to the standard.

Other issues involved in the LCA methodology of LEED include the independent and context dependence of credit weights. As a result of synergies, credits do not always work independent but together. This is the basis for integrated design and the LEED 2009 weighting system does not yet internalize these considerations, because of the design requirement to provide static, independent weights. Furthermore, the requirement for positive integers constrains the range of variation available within a 100-point system. This specification requires rounding fractional points and fosters a manual point reallocation step, which is a result of the design constraints. The reallocation process also involved some value judgments along with the weighting exercise. Partly because of gaps in the data, strict application of the TRACI-NIST tool would have made some credits worth almost nothing, especially for the categories of indoor air quality and human health, but it was important to the LEED 2009 development team to retain the existing credits, even those associated with relatively small environmental benefit, making all at least one point in the new system.

According to the USGBC these issues clearly indicate the potential value of a dynamic, context-sensitive weighting system. The LEED 2009 weightings tool provides a prototype for the capabilities needed for dynamic weighting in a future version of LEED. However, such a step would require substantial effort to move form the current prototype to an enterprise level software system usable by project teams and capable of accommodating the breath of situations encountered in practice. Additionally, such a system would require substantial changes in LEED educational and certification processes. It is recommended that LEED use the rounded points as well as weighted adjustments to previous credits to implement an M&R credit of resource conservation through design.

Materials & Resources credit 7: Resource Conservation through design. For environmental benefits of virgin resource consumption reduction, it is recommended that a framework for this credit be taken from the DGNB design for disassembly criterion, the ANSI standard for design of multi-functional assembly and design service life plan, and SBTool's materials use criteria. Each of these strategies has been previously discussed and this credit inclusion is one of the most important (MR) categories for the USGBC to consider in the future.

Finally, during the revision process of LEED-NC v.3, the USGBC did not change any achievement criteria where credit weightings were unaffected (e.g., recycled content, regional materials, construction waste management). The USGBC used the TRACI impact categories to revise credit weightings, however, did not take into account the rapidly increasing commitment to sustainable development. It is the opinion of the author that the USGBC continually raise the bar in achievement levels for both MR credits and other categories to ensure continued environmental responsibility relative to the growth of the sustainability movement. This theory is recognized in ASHRAE standard 189.1p with the increase in achievement % of certified wood from 50% to 60%, bio-based materials from 2.5% to 5%, and regional materials from 10% to 15%.

The LEED-NC scorecards of the existing system and the revised framework are listed in Tables 4-5 and 4-6.

Summary

Despite the recent revisions to the LEED rating system, there is significant potential for improvements to the materials and resources category to include additional credits, reallocation of weightings, and an overall increase to the rigor of credit achievement to bring LEED to more comparable levels of environmental responsibility relative to existing standards and rating systems. LEED has attempted to improve accounting to previous versions with an incorporation of environmental building impacts to justify credit weightings, as well as award points for regional differences. However, the MR category is still limited and weak in reducing the environmental impacts of building construction in comparison to building assessment systems throughout the world.

The materials and resources category of LEED has many implications on the future of the built environment and currently is among the weakest categories of LEED. There are several opportunities in the areas of life cycle assessment, resource conservation through design, construction waste management, building reuse, and building materials selection to incorporate more environmentally responsible building practices to recognize a more sustainable future for generations to come.

CHAPTER 5
RECOMMENDATIONS FOR FURTHER RESEARCH

This study brings up several theories and concepts that contain high ambiguity in the field of high performance green building. The recommendations made to the improvements of LEED are based on consensus criteria among international assessment standards and rating systems that have no claim of superiority in achievement criteria, weighting methodology, or criteria selection. A study on the comparison of performance of the rating systems would help in determining the superiority of one system over another.

With recent additions to the LEED rating system as well as the exponential increase in registered projects, research statistics should be performed that are similar in scope to the White Paper on Sustainability 2003. The USGBC could learn which of the credits and their associated new weighting hold value to the project owner as well as those credits that are least desirable. This information could prove invaluable to the research and development of sustainable building practices for future versions of building assessment systems.

Additionally, research could be conducted to discover if the current state of assessment standards' M&R category, on average produces significant environmental results in the reduction of negative environmental impacts. If there is no sizeable contribution, research efforts could be re-directed for a total re-evaluation of materials and resource selection throughout building assessment systems.

Finally, one of the most significant aspects of green building with the most potential for making a difference to reducing the negative impacts of building development is building reuse of both structural and interior elements. With the building industry accounting for more than 40% of raw materials consumption annually, research that could facilitate a paradigm shift to major renovations of the existing building stock, as well as design for resource conservation through design could have significant positive impacts on the built environment for years to come.

Table 2-1. The principles of sustainable construction

1.	Reduce resource consumption (reduce).
2.	Reuse resources (reuse).
3.	Use recyclable resources (recycle).
4.	Protect nature (nature).
5.	Eliminate toxics (toxics).
6.	Apply life-cycle costing (economics).
7.	Focus on quality (quality).

Table 2-2. High-performance green building as defined by GGGC

1.	A project created via cooperation among building owners, facility managers, users, designers and construction professionals through a collaborative team approach.
2.	A project that engages the local and regional communities in all stages of the process, including design, construction, and occupancy.
3.	A project that conceptualizes a number of systems that, when integrated, can bring efficiencies to mechanical operation and human performance.
4.	A project that considers the true costs of a building's impact on the local and regional environment.
5.	A project that considers the life-cycle costs of a product or system. These are costs associated with its manufacture, operation, maintenance, and disposal.
6.	A building that creates opportunities for interaction with the natural environment and defers to contextual issues such as climate, orientation, and other influences.
7.	A building that uses resources efficiently and maximizes use of local building materials.
8.	A project that minimizes demolition and construction wastes and uses products that minimize waste in their production or disposal.
9.	A building that is energy- and resource-efficient.
10.	A building that can be easily reconfigured and reused.
11.	A building with healthy indoor environments.
12.	A project that uses appropriate technologies, including natural and low-tech products and systems, before applying complex or resource-intensive solutions.
13.	A building that includes an environmentally sound operations and maintenance regimen.
14.	A project that educates building occupants and users to the philosophies, strategies, and controls included in the design, construction, and maintenance of the project.

Table 2-3. ISO 14040 format

LCA Phase	Primary Activities
Goal & Scope Definition	Life Cycle Definition Functional Unit Definition System Boundary Definition Data Quality Determination
Inventory Analysis	Data Collection Quantification of inputs/outputs
Impact Assessment	Classification Characterization Weighting
Interpretation	Reporting Critical Review

Table 2-4. Principles of design for disassembly as applied to buildings

1. Use recycled and recyclable materials.
2. Minimize the number of types of materials.
3. Avoid toxic and hazardous materials.
4. Avoid composite materials & make inseparable products from the same material.
5. Avoid secondary finishes to materials.
6. Provide standard and permanent identification of material types.
7. Minimize the number of different types of components.
8. Use mechanical rather than chemical connections.
9. Use an open building system with interchangeable parts.
10. Use modular design.
11. Use assembly technologies compatible with standard building practice.
12. Separate the structure from the cladding.
13. Provide access to all building components.
14. Design components sized to suit handling at all stages.
15. Provide for handling components during assembly and disassembly.
16. Provide adequate tolerance to allow for disassembly.
17. Minimize numbers of fasteners and connectors.
18. Minimize the types of connectors.
19. Design joints and connectors to withstand repeated assembly and disassembly.
20. Allow for parallel disassembly.
21. Provide permanent identification for each component.
22. Use a standard structural grid.
23. Use prefabricated subassemblies.
24. Use lightweight materials and components.
25. Identify the point of disassembly permanently.
26. Provide spare parts and storage for them.
27. Retain information on the building and its assembly process.

Table 2-5. Opportunities and constraints of deconstruction

Opportunities	Constraints
Management of hazardous materials	Increase worker safety/health hazard
Reduction in landfill debris	More time required
Economic activity via reused materials	Site storage for recovered materials
Preservation of virgin resources	Lack of standards for certain recovered materials reuse
Removal of inefficient/obsolete structures	Lack of established supply/demand chains
Reduction in site nuisance compared to demolition	None

Table 2-6. Building assessment standards and rating systems

Rating System	Organization	Country
LEED version 3	USGBC	United States
ANSI 01-2008P	GBI/ANSI	Canada/United States
DGNB certificate	DGNB	Germany
SBTool	iiSBE	International
ASHRAE 189.1p	ASHRAE/IESNA/USGBC	United States

Table 2-7. Whole system comparison of LEED v2.2-v3.0

Category	Version 2.2		Version 3	
	Pts	%	Pts	%
Water Efficiency	5	7%	10	9%
Energy & Atmosphere	17	25%	35	32%
Materials & Resources	13	19%	14	13%
Indoor Environment Quality	15	22%	15	14%
Innovation & Design	5	7%	6	5%
Regional Priority	0	0%	4	4%
Total	69	100%	110	100%

Table 2-8. LEED 2009 weighting process

1. Building impacts are estimated based on a building prototype.
2. Impacts are described with respect to 13 TRACI impact categories
3. Impacts are associated with up to 6 groups of credits (activity groups)-this assigns some number of potential points to groups of credits.
4. Points are allocated proportionally to credits within an activity group=the default is that each credit in the group contributes equally to the impact associated with the category and consequently receives an equal score.
5. Some credit weights are adjusted to reflect the relative performance of individual credits-this changes the distribution of points within a category (points in other groups are not changed).
6. Impact scores for each activity group are adjusted based on individual and aggregate capabilities of existing credits (e.g.,, control over transportation)-this means “uncontrolled” points from transportation are distributed proportionally across the other groups.
7. Credit weights for the 13 TRACI impact categories are integrated by taking a weighted average across all impact categories based on weights from the TRACI/BEES exercise.
8. Combined credit weights are rounded tot the nearest whole number and the “residual” created during the rounded is tallied.
9. Residual points (i.e.,, points created by rounding) are manually reallocated across the system based on specific rules- the LSC directed that points be allocated with priority for green house gas emissions reduction potential.
10. Results are transferred back to the existing scorecard for each system.

Table 2-9. Summary of information sources used for each impact category

TRACI category	BEES weights	Description of category	Information Source
Greenhouse gas emissions	25	Operational greenhouse gas emissions (C02e/yr)	Empirical calculations based on CBECS
Fossil fuel depletion	9	Consumption of non-renewable, fossil fuels	SimaPro/USA Input Output 98 library
Water use	7	Consumption of water *throughout the life cycle of a building*	SimaPro/USA Input Output 98 library
Land use	5	Consumption of land *throughout the life cycle of a building*	SimaPro/USA Input Output 98 library
Acidification	3	Generation of “acid rain” emissions associated with acidification *throughout the life-cycle of a building*	SimaPro/USA Input Output 98 library/Ecocalculator
Eutrophication	5	Generation of nutrient pollution *throughout the life-cycle of a building*	SimaPro/USA Input Output 98 library/Ecocalculator
Ozone depletion	2	Generation of ozone depleting emissions *throughout the life-cycle of a building*	SimaPro/USA Input Output 98 library/Ecocalculator
Smog formation	4	Generation of smog forming emissions *throughout the life-cycle of a building*	SimaPro/USA Input Output 98 library/Ecocalculator
Ecotoxicity	6	Generation of ecotoxic pollutants *throughout the life-cycle of a building* Generation of ecotoxic plants *at the site*	SimaPro/USA Input Output 98 library/Ecocalculator
Particulates	8	Generation of particulate emissions *throughout the life-cycle of a building*	SimaPro/USA Input Output 98 library/Ecocalculator
Human health-cancer	7	Generation of cancer-causing compounds *throughout the life-cycle of a building*	SimaPro/USA Input Output 98 library
Human health-non cancer	4	Generation of non-cancer-causing compounds *throughout the life-cycle of a building*	SimaPro/USA Input Output 98 library
Indoor environmental quality	15	Impacts on building occupants and the indoor environment	No model; association based on credit function

Table 2-10. LEED 2009 MR credits and relative emphasis to whole rating system.

MR Credit	Points	% Weighting among MR	Weighting among LEED 2009
Prerequisite 1: Storage and collection of recyclables	Required	n/a	n/a
MRc1.1: Building Reuse: maintain existing walls, floors, and roof	1-3 pts	21.4%	3%
MRc1.2: Building Reuse: maintain interior non structural elements	1 pt	7.10%	1%
MRc2: Construction Waste Management	1-2 pts	14.30%	1%
MRc3: Materials Reuse	1-2 pts	14.30%	1%
MRc4: Recycled Content	1-2 pts	14.30%	1%
MRc5: Regional Materials	1-2 pts	14.30%	1%
MRc6: Rapidly Renewable Materials	1 pt	7.15%	1%
MRc7: Certified Wood	1 pt	7.15%	1%
Total	14 pts	100%	14%

Table 2-11. Proposed ANSI standard 01-2008p resources & materials

R/M credit	Points	% In R/M	% Within whole system
10.1.1 Assemblies-structural system/envelope using LCA calculator *or*	33 pts *Or*	25.98%	3.36%
10.1.2 Assemblies using recycled, bio-based and regional materials	25 pts	18.92%	2.55%
10.2 Furnishings, finishes, and fit-outs	17 pts	13.39%	1.73%
10.3 Other material properties-off site salvaged materials and certified wood	12 pts	9.45%	1.22%
10.4 Reuse of existing structure-systems, facades, non-structural elements	n/a for new construction	n/a	n/a
10.5 Reduction, reuse, and recycling of waste	9 pts	7.10%	0.917%
10.6 Resource conservation through design	14 pts	11.02%	1.02%
10.7 Building envelope- roofing membrane, roof/wall openings, foundation systems, below grade wall slabs, and flashings	30 pts	23.62%	3.06%
10.8 Air Barriers	6 pts	4.72%	0.61%
10.9 Vapor Retarders	6 pts	4.72%	0.61%
Total	127 pts	100%	12.93%

Table 2-12. DGNB certificate resources and materials credits

Criterion	Points	% Within MR	% of whole system
C1:Global warming potential-LCA* required for building structure and materials used, EnEV 2007 for operational inputs	30 points	13.33%	3.5%
C2:Ozone depletion potential- LCA* required for building structure and materials used, EnEV 2007 for operational inputs	5 points	2.22%	0.6%
C3:Photochemical ozone depletion potential-LCA* required for building structure and materials used, EnEV 2007 for operational inputs	5 points	2.22%	0.6%
C4: Acidification potential- LCA* required for building structure and materials used, EnEV 2007 for operational inputs	10 points	4.44%	1.2%
C5: Eutrophication potential- LCA* required for building structure and materials used, EnEV 2007 for operational inputs	10 points	4.44%	1.2%
C6: Risks to the local environment- materials listed individually and per product basis: Items that fall under REACH and biocide guidelines, etc.	30 points	13.33%	3.5%
C8: Other impacts on the global environment- certified wood by Forest Stewardship Council (FSC) or PEFC	10 points	4.44%	1.2%
C10: Non-renewable primary energy demand reduction calculated over construction, reconditioning, operation, and disassembly. LCA* required for building structure and materials used	30 points	13.33%	3.5%
C11: Total primary energy demands - LCA required for building structure and materials used, EnEV 2007 for operational inputs	20 points	8.89%	2.34%
C16: Building related life cycle costs- production costs, follow-up costs, disposal/disassembly costs	30 points	13.33%	3.5%
C40: Ease of cleaning and maintenance of the structure.	20 points	8.89%	2.34%
C42:Ease of deconstruction, recycling, & dismantling	20 points	8.89%	2.34%
C48: Construction site/ process-low waste subsection	5 points	2.22%	0.6%
Total	225 pts	100%	26.4%

Table 2-13. Materials & resources within SBTool

Criteria	Weight within group	Weight within system
B4.1 Reuse of existing structure	16.7%	2.3%
B1.1 Life cycle non renewable energy: Annualized non-renewable primary energy embodied in construction materials.*	4.1%	1.0%
B4.2 Minimal use of finishing Materials	7.4%	1.0%
B4.3 Minimal use of virgin materials	3.7%	0.5%
B4.4 Use of durable materials	7.4%	1.0%
B4.5 Use of salvaged materials	11.1%	1.5%
B4.6 Use of recycled materials from off site sources	7.4%	1.0%
B4.7 Use of bio-based sources	11.1%	1.5%
B4.8 Use of cement supplementing materials in concrete	16.7%	2.3%
B4.9 Use of materials that are locally produced	7.4%	1.0%
B4.10 Design for disassembly, reuse, and recycling	11.1%	1.5%
C1.Annualized GHC emissions embodied in construction materials	4.0%	1.5%
C3 Solid wastes (during construction and during occupancy)	9.4%	3.5%
Total	Various categories	19.6%

* Use of appropriate LCA method required or use of embodied energy spreadsheet accessible in excel spreadsheet.

Table 4-1. LEED MR credit comparison to ASHRAE 189.1p

System	LEED		ASHRAE 189.1p	
Criterion	Achievement	% of system	Achievement	% of system
Collection of recyclables	Storage/collection glass, plastics, metals, paper, cardboard	Required	Storage/collection glass, plastics, metals, paper, cardboard, fluorescent, HID bulbs	Required
Exterior building reuse	55%,75%, or 95%	3%	None	None
Interior building reuse	50% by area of interior walls, floors, ceilings	1%	None	None
Construction waste management	50% or 75% Diversion based on weight or vol.	2%	50% Diversion based on weight or vol. and max waste generation of 42 c.y. or 12,000 lbs/ 10,000 sq. ft	Required
Materials reuse	5% or 10% Based on total materials costs	2%	None	None
Recycled content	10% or 20% Based on total materials costs	2%	10% Based on total materials costs	Required: If choosing prescriptive path
Regional materials	10%-20% Based on total materials costs extracted, processed, and manufactured within 500 miles	2%	15% Based on total materials costs extracted, processed, and manufactured within 500 miles	Required: If choosing prescriptive path
Rapidly renewable resources	2.5% based on total materials cost (bio-based materials with 10-year or less rotation	1%	5% based on total materials costs (50% content bio-based materials, any rotation period)	Required: If choosing prescriptive path
Certified wood	50% based on total wood costs must be FSC certified	1%	60% based on total wood costs must be in certified in accordance with forestry guidelines	Required: If choosing prescriptive path
LCA	None	None	Performance path procedures in accordance with ISO 14040	Required: If choosing performance path

Table 4-2. LEED MR credit comparison to ANSI 01-2008P

System	LEED		ANSI 01-2008P	
Criterion	Achievement	% of system	Achievement	% of system
Collection of recyclables	Storage/collection glass, plastics, metals, paper, cardboard	Required	Storage/collection glass, plastics, metal, paper, cardboard	0.2%
Exterior building reuse	55%,75%, or 95%	3%	10%-95%	1.22%
Interior building reuse	50% by area of interior walls, floors, ceilings	1%	10%-95%	0.61%
Construction waste management	50% or 75% Diversion based on weight or volume	2%	25%-75% Diversion based on weight or volume	0.71%
Materials reuse	5% or 10% Based on total materials costs	2%	1%-9% Based on total materials costs	0.61%
Recycled content	10% or 20% Based on total materials costs	2%	1%-20% Based on total materials costs	0.81% Prescriptive path
Regional materials	10%-20% Based on total materials costs extracted, processed, and manufactured within 500 miles	2%	1%-20% Based on total materials costs harvested, extracted, process, and manufactured within 500 miles	1.43% Prescriptive path
Rapidly renewable resources	2.5% based on total materials cost (bio-based materials with 10-year or less rotation	1%	1%-20% Structural and finishes: bio-based materials any rotation	0.55% Prescriptive path
Certified wood	50% based on total wood costs must be FSC certified	1%	10%-60% Based on total wood costs must be certified (numerous agencies)	0.61%
Interior finishes, fit outs, and furnishing	None	None	Recycled, bio-based, regional materials, and LCA (various %)	1.73%
LCA (structural systems and envelope)	None	None	Conduct LCA using Green Globes LCA calculator for building assemblies	3.36% Performance path
Resource conservation through design	None	None	Architect letter on service life plan, multi-functional assemblies, & DfDD	1.43%

Table 4-3. LEED MR credit comparison to DGNB certificate

System	LEED		DGNB Certificate	
Criterion	Achievement	% of system	Achievement	% of system
Collection of recyclables	Storage/collection glass, plastics, metals, paper, cardboard	Required	None	None
Exterior building reuse	55%,75%, or 95%	3%	None	None
Interior building reuse	50% by area of interior walls, floors, ceilings	1%	None	None
Construction waste management	50% or 75% Diversion based on weight or volume	2%	3rd Party assessment based on computer model	0.6%
Materials reuse	5% or 10% Based on total materials costs	2%	None	None
Recycled content	10% or 20% Based on total materials costs	2%	None	None
Regional materials	10%-20% Based on total materials costs extracted, processed, and manufactured within 500 miles	2%	None	None
Rapidly renewable resources	2.5% based on total materials cost (bio-based materials with 10-year or less rotation	1%	None	None
Certified wood	50% based on total wood costs must be FSC certified	1%	3rd Party assessment FSC or PEFC certified	1.2%
LCA	None	None	3rd Party assessment, use ISO 14040	3.25%
Resource conservation in design	None	None	See criteria in literature review	2.34%
Risks to local environment	Integrated in IEQ	Integrated in IEQ	REACH guidelines, prohibited items	3.5%
Life cycle costs	None	None	3rd Party assessment	2.34%
Ease of cleaning/maintenance	None	None	3rd Party assessment	2.34%

Table 4-4. LEED MR credit comparisons to SBTool

System	LEED		SBTool	
Criterion	Achievement	% of system	Achievement	% of system
Collection of recyclables	Storage/collection glass, plastics, metals, paper, cardboard	Required	Storage/collection glass, plastics, metals, paper, cardboard	Required
Exterior building reuse	55%,75%, or 95%	3%	25%-85% based on area	2.3%
Interior building reuse	50% by area of interior walls, floors, ceilings	1%	None	None
Construction waste management	50% or 75% Diversion based on weight or volume	2%	Unavailable	1.4%
Materials reuse	5% or 10% Based on total materials costs	2%	1%-15% based on total materials costs	1.5%
Recycled content	10% or 20% Based on total materials costs	2%	7%-25% based on total materials costs and 8%-50% by volume of the use of cement supplementary materials	3.3%
Regional materials	10%-20% Based on total materials costs extracted, processed, and manufactured within 500 miles	2%	42%-90% based on total materials costs, no distance specified	1.0%
Rapidly renewable resources	2.5% based on total materials cost (bio-based materials with 10-year or less rotation	1%	9%-15% based on total materials costs of bio-based materials (any rotation)	1.5%
Certified wood	50% based on total wood costs must be FSC certified	1%	Required for bio-based materials	N/A
Interior finishes, fit outs, and furnishing	None	None	Use durable finish materials (3%-5%), minimal use of finish and virgin materials (8-80%) based on area left exposed and total materials costs of non-virgin origin	2.5%
LCA	None	None	embodied energy workbook or ISO 14040	2.5%
Resource conservation in design	None	None	Design for disassembly- 3rd party assessment	1.5%

Table 4-5. Existing LEED-NC scorecard

Materials & Resources	Points
MRp1: Storage & collection of recyclables	Required
MRc1.1: Building reuse-maintain 55-75-95% existing walls, floors, roof	1-3 points
MRc1.2: Building reuse-maintain 50% interior floors, ceiling, doors, etc	1 point
MRc2: Construction waste management divert 50-75% from disposal	1-2 points
MRc3: Material reuse, 5-10%	1-2 points
MRc4: Recycled content 10-20% (postconsumer +1/2 preconsumer)	1-2 points
MRc5: Regional materials,10-20% extracted, processed, manufactured, etc. <500 miles	1-2 points
MRc6: Rapidly renewable materials, 2.5%	1 point
MRc7: Certified wood, 50% FSC certified	1 point
Total in materials & resources	14 points

Table 4-6. Proposed LEED-NC scorecard

Materials & Resources	Points
MRp1: Storage & collection of recyclables	Required
MRc1.1: Building reuse-maintain 55-75-95% existing walls, floors, roof	3-7 bonus points
MRc1.2: Building reuse-maintain 50% interior floors, ceiling, doors, etc	2 points
MRc2: Construction waste management divert 50-75% from disposal	Required;1 point
MRc3: Material reuse, 5%	1 point
MRc4: Recycled content 10-20% (postconsumer +1/2 preconsumer)	Required;1 point
MRc5: Regional materials,15-20% extracted, processed, manufactured, etc. <500 miles	Required; 1 point
MRc6: Rapidly renewable materials, 2.5%; bio-based materials, 5% certified wood, 60%; LCA , showing 5% improvement of four impacts	1-6 points
MRc7: Resource conservation through design, DfDD, service life plan, multi-functional assemblies, minimal finish materials, use of durable interior materials	1-6 points
Total in Materials & Resources	18 points; 7 bonus points

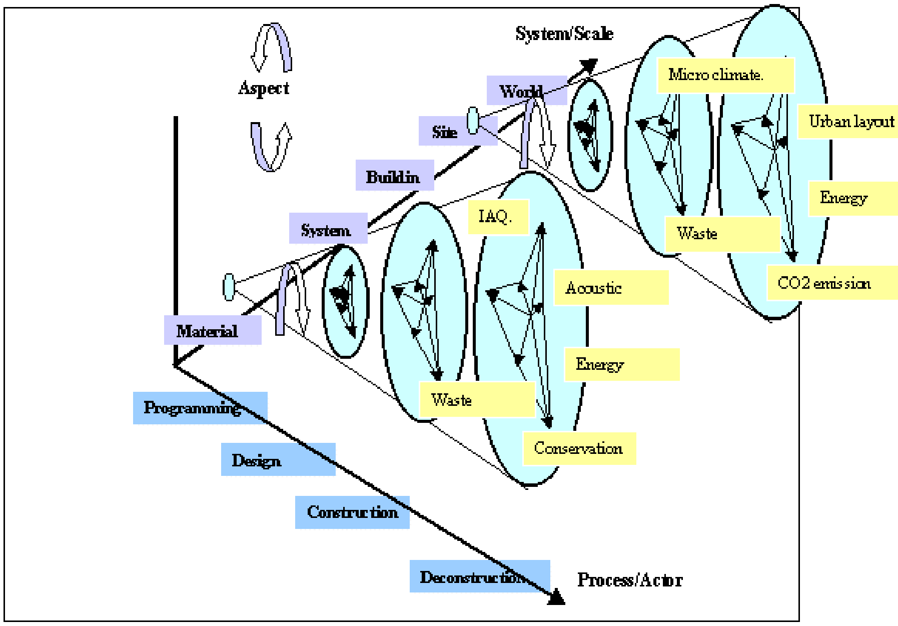

Figure 2-1. Framework for sustainable construction (drawing by Bilge Celik).

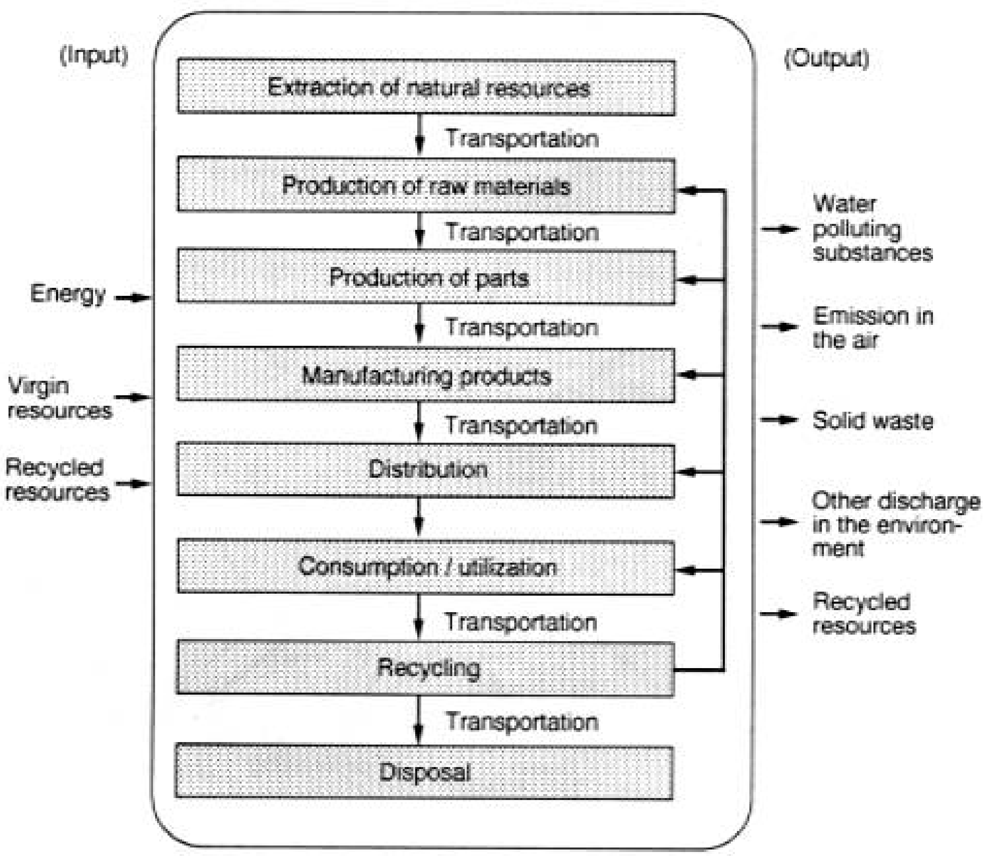

Figure 2-2. LCA concept (Meadows)

APPENDIX A
MATERIALS AND RESOURCES CREDIT FRAMEWORK

MR prerequisite 1: Storage and Collection of Recyclables and Discarded goods

Required

Intent

To facilitate the reduction of waste generated by building occupants that is hauled to and disposed of in landfills.

Requirements

Provide an easily accessible area that serves the entire building and is dedicated to the collection and storage of non-hazardous materials for recycling. Materials must include, at a minimum: paper, corrugated cardboard, glass, plastics, metals.
Provide an area that serves the entire building for the collection and storage of fluorescent and HID lamps and ballasts and facilitates proper disposal and/or recycling according to state and local hazardous waste requirements. The requirements for recycling area are listed below:

Building sq. footage	Min. recycling area (sf)
0-5,000	82
5,001-15,000	125
15,001-50,000	175
50,001-100,000	225
100,001-200,000	275
200,001-greater	500

Suggested Documentation

- Construction drawings, specifications, and related submittals.

Potential Technologies and Strategies

Designate and area for recyclable collection and storage that is appropriately sized and located in a convenient area. Identify local waste handlers and buyers for glass, plastics, metals, office paper, newspaper, cardboard, organic wastes, HID lamps and ballasts. Instruct occupants on recycling procedures. Consider employing cardboard balers, aluminum can crushers, recycling chutes, and other waste management strategies to further enhance the recycling program.

MR credit 1.1 Building Reuse- Maintain Existing Walls, Floors, and Roof

3-7 Points

Intent

To extend the life cycle of existing building stock, conserve natural resources, retain cultural resources, reduce waste and reduce environmental impacts of new buildings as they relate to materials manufacturing and transport.

Requirements

Maintain the existing building structure (including structural floor and roof decking) and envelop (the exterior skin and framing, excluding window assemblies and non-structural roofing material). The minimum percentage building reuse for each point threshold is as follows:

Building Reuse	**Points**
55%	3
65%	4
75%	5
85%	6
95%	7

Suggested Documentation

- Construction drawings, cut sheets, and specification
- Calculations of floor, roof, and wall area retained

Potential Technologies & Strategies

Assess the project for nonpolluting and renewable energy potential including solar, wind, geothermal, low-impact, hydro, biomass and biogas strategies. When applying these strategies, take advantage of net metering with the local utility.

MR Credit 1.2: Building Reuse-Maintain Interior Nonstructural Elements

2 Points

Intent

To extend the lifecycle of existing building stock, conserve resources, retain cultural resources, reduce waste and reduce environmental impacts of new buildings as they relate to materials manufacturing and transport.

Requirements

Use existing interior nonstructural elements (e.g.,, interior walls, doors, floor coverings, and ceiling systems) in at least 50% (by area) of the completed building, including additions. If the project includes and addition with square footage more than 4 times the square footage of the existing building, this credit is non applicable.

Suggested Documentation

- Construction drawings, cut sheets, and specifications
- Calculations of interior walls, doors, floor coverings, and ceiling systems area reused.

Potential Technologies & Strategies

- Consider reusing existing building structures, envelopes, and interior nonstructural elements. Remove elements that pose a contamination risk to building occupants, and upgrade components that would improve energy and water efficiency such as mechanical systems and plumbing fixtures. Quantify the extent of building reuse.

MR Credit 2: Construction Waste Management

1 point

Intent

To divert construction and demolition debris from disposal in landfills and incineration facilities. Redirect recyclable recovered resources back to the manufacturing process and reusable materials to appropriate sites.

Requirements

Total Waste: For new building projects on sites with less than 5% existing buildings, structures, or hardscape, the total amount of construction waste generated on a project shall not exceed 42 cubic yards or 12,000 lbs per 10,000 square ft (35 cubic meters or 6000 kg per 1000 sq meters) of new building floor area. This shall apply to all waste whether diverted, land filled, incinerated or otherwise disposed of.

Recycle and/or salvage non-hazardous construction and demolition debris. Develop and implement a construction waste management plan that, at a minimum, identifies the materials to be diverted from disposal and whether the materials will be sorted on-site or commingled. Excavated soil and land-clearing debris do not contribute to this credit. Calculations can be done by weight or volume, but must be consistent throughout. The minimum percentage debris to be recycled or salvaged is as follows:

Recycled or Salvaged	Points
50%	Required
75%	1 point

Suggested Documentation

- Construction Waste Management Plan
- Tipping Records
- Consistent calculations of waste generation (weight or volume)

Potential Technologies & Strategies

Establish goals for diversion from disposal in landfills and incineration facilities and adopt a construction waste management plan to achieve these goals. Consider recycling cardboard, metal, brick, mineral fiber panel, concrete, plastic, clean wood, glass, gypsum wallboard, carpet and insulation. Construction debris processed into a recycled content commodity that has an open market value (e.g.,, wood derived fuel [WDF], alternative daily cover material, etc.) may be applied to the construction waste calculation. Designate a specific area(s) on the construction site for segregated or commingled collection of recyclable materials, and track recycling efforts throughout the construction process. Identify construction haulers and recyclers to handle the designated materials. Note that diversion may include donation of materials to charitable organizations and salvage of materials on-site.

MR Credit 3: Materials Reuse

1 point

Intent

To reuse building materials and products to reduce demand for virgin materials and reduce waste, thereby lessening impacts associated with the extraction and processing of virgin resources

Requirements

Use salvaged, refurbished or reused materials, the sum of which constitutes at least 5% or 10%, based on cost, of the total value of materials on the project. The minimum percentage materials reused for each point threshold is as follows:

Reused Materials	Points
5%	1

Mechanical, electrical, plumbing fire safety systems, and transportation devices shall not be included in the calculations except for piping, plumbing fixtures, ductwork, conduit, wiring, cabling, and elevator and escalator framing. Calculations shall include materials permanently installed in the project. A value of 45% of the total construction cost may be used in lieu of the actual total cost of materials components.

Suggested Submittals

- Total project material cost or default 45% of project costs (divisions 2-10)
- Table of salvage/reused materials, source/vendor, and costs
- Narrative of reuse strategy

Potential Technologies & Strategies

Identify opportunities to incorporate salvaged materials into the building design, and research potential material suppliers. Consider salvaged materials such as beams and posts, flooring, paneling, doors and frames, cabinetry and furniture, brick, and decorative items.

MR Credit 4: Recycled Content and Recyclable Materials

1 point

Intent

To increase demand for building products that incorporate recycled content and recyclable materials, thereby reducing impacts resulting from extraction and processing of virgin materials.

Requirements

Use materials with recycled content such that the sum of postconsumer recycled content plus ½ of the preconsumer content constitutes at least 10%, based on cost, of the total value of the materials in the project.

Use recyclable building materials in assemblies to include copper, aluminum and steel. The minimum percentage materials recycled for each point threshold is as follows:

Recyclable Materials	Points
10%	Required
20%	1

The recycled content value of a material assembly is determined by weight. The recycled fraction of the assembly is then multiplied by the cost of assembly to determine the recycled content value.

Mechanical, electrical, plumbing fire safety systems, and transportation devices shall not be included in the calculations except for piping, plumbing fixtures, ductwork, conduit, wiring, cabling, and elevator and escalator framing. Calculations shall include materials permanently installed in the project. A value of 45% of the total construction cost may be used in lieu of the actual total cost of materials components.

Suggested Submittals

- Total material costs or default 45% of project costs (divisions 2-10)
- Table of recycled materials, source/vendor, and costs
- Narrative of recycling strategy
- Construction drawings, specifications, and submittals for recyclable materials

Potential Technologies & Strategies

Establish a project goal for recycled content and recyclable materials, and identify materials suppliers that can achieve this goal. During construction, ensure that the specified recycled content materials are installed. Consider a range of environmental, economic, and performance attributes when selecting products and materials.

MR Credit 5: Regional Materials

1 Point

Intent

To increase demand for building materials and products that are extracted and manufactured within the region, thereby supporting the use of indigenous resources and reducing the environmental impacts resulting from transportation.

Requirements

Use building materials or products that have been extracted, harvested or recovered, as well as manufactured, within 500 miles of the project site for a minimum of 10%, based on cost, of the total materials value. If only a fraction of a product or material is extracted, harvested, or recovered and manufactured locally, then only that percentage (by weight) can contribute to the regional value. The minimum percentage regional materials for each point threshold is as follows:

Regional Materials	Points
15%	Required
20%	1

Mechanical, electrical, plumbing fire safety systems, and transportation devices shall not be included in the calculations except for piping, plumbing fixtures, ductwork, conduit, wiring, cabling, and elevator and escalator framing. Calculations shall include materials permanently installed in the project. A value of 45% of the total construction cost may be used in lieu of the actual total cost of materials components.

Suggested Documentation

- Construction drawings, specifications, and related submittals
- Total material costs or default 45% of project costs (divisions 2-10)
- Table of regional materials and calculations of appropriate percentages

Potential Technologies & Strategies

Establish a project goal for locally sourced materials, and identify materials and material suppliers that can achieve this goal. During construction, ensure that the specified local materials are installed, and quantify the total percentage of local materials installed. Consider a range of environmental, economic, and performance attributes when selecting products and materials.

MR Credit 6: Sustainable Materials Selection

1-6 Points

Intent

To encourage sustainable forestry management practices, selection of bio-based and rapidly renewable resources, and account for environmental impacts associated with materials selection.

Requirements

Use rapidly renewable building materials and products for 2.5% of the total value of all building materials and products used in the project, based on costs. Rapidly renewable building materials and products are made from plants that are typically harvested within a 10-year or shorter cycle (1 point)

Suggested Documentation

- Construction drawings, specifications, and related submittals
- Total material costs or default 45% of project costs (divisions 2-10)
- Table of rapidly renewable materials and costs

Use bio-based building materials and products for 5% of the total value of all building materials and products, based on costs. Bio-based materials include wood and agricultural products that may be on a long-rotation basis. (1 point)

Suggested Documentation

- Construction drawings, specifications, and related submittals
- Total material costs or default 45% of project costs (divisions 2-10)
- Table of bio-based materials and costs

Use a minimum of 60% (based on cost) of wood-based materials and products including, but not limited to, structural framing, sheathing, flooring, sub-flooring, wood window sash and frames, doors, and architectural millwork. It shall be tracked through a chain of custody process either by physical separation or percentage-based approaches. Acceptable certified wood content documentation shall be provided by sources certified through a forest certification system with principles, criteria, and standards developed using ISO/IEC Guide 59, or the WTO Technical Barriers to Trade. Include only materials permanently installed in the project. (1 point)

Suggested Documentation

- Construction drawings, specifications, and related submittals
- Total material costs or default 45% of project costs (divisions 2-10)
- Chain-of-custody from appropriate forestry certification program
- Table of project wood costs

A life cycle assessment shall be performed in accordance with ISO 14040 for a minimum of four building alternatives, resulting in a 5% improvement over the other alternative. The impact categories are: land use, resource use, climate change, ozone layer depletion, human health effects, ecotoxicity, smog, acidification, and eutrophication. (3 points)

Suggested Documentation

- Construction drawings, specifications, and related submittals
- Input and results from appropriate LCA method using ISO 14040 with 3rd party analysis and verification.

Potential Technologies & Strategies

Establish a project goal for bio-based, rapidly renewable resources, and certified wood. Identify products and suppliers that can support achievement of this goal. Consider materials such as wood, bamboo, wool, cotton insulation, agrifiber, linoleum, wheatboard, strawboard, and cork. During construction, ensure that the specified materials are installed.

For LCA, perform a life cycle inventory that accounts for all individual environmental flows to and from the materials components in a building throughout its life cycle. Compare the two building alternatives using a published third-party impact indicator method and report the LCA findings to include documentation of critical peer review by a third party including the results from the review and reviewer's name and contact information.

MR Credit 7: Resource Conservation through Design

1-6 Points

Intent

To facilitate longer service life buildings, materials reuse by future generations, and mitigate the environmental impacts of major renovations to include demolition and demand for virgin resources.

Requirements

A Building Service Life Plan was prepared and includes: (1 point)

- Service life estimates for structural, building envelope, and hardscape materials that need to be replace during the life of the building, not including mechanical and electrical assemblies.
- Expected service life for building assemblies and materials that require inspection and/or need to be replaced during the service life of the building, where service life was based on the following:

    - Temporary buildings<10years
    - Medium-life buildings e.g., industrial and parking structures>5 years
    - Long life building types >50 years

- Documentation of the project design service life, the basis for determination and the following details for each assembly or component used in the building:
    - Building assembly and material description
    - Design service life in years
    - Predicted service life in years
    - Effects of failure
    - Maintenance frequency and maintenance access

Informational Reference(s)

- CSA S478-95
- ISO 15686

Multi-Functional Assemblies (1 point)

- The architect or design professional to provide letter documentation describing how the building design uses assemblies that perform multiple functions. The letter included specific examples, including applicable calculations, drawings, or specifications.

Design for Disassembly/Deconstruction (2 points)

- The architect or design professional to provide letter documentation describing the building design of modular and panelized elements, components, sub-components, and materials for reuse, remanufacture, and/or biodegrade.
- Provide record of the construction process to include as-built conditions**,** a deconstruction plan based upon the construction process**,** and adaptations to the building over its life.
- Design is to encompass full and partial disassembly for maintenance purposes over the life of the building.

Minimal Use of Finish Materials (1 point)

- The percent of above-grade interior floor, wall, or ceiling surface areas in which structural elements are left exposed is approximately:

Percent Area	Points
15%	1

Suggested Documentation

- Letters and building models from the architect or design professional
- Construction drawings, specifications, and related submittals
- Formal building service life plan

Potential Technologies & Strategies

Consider the design for partial and full disassembly of building elements, components, and materials. Specify interior durable materials and products as well as design for longer service life. Design the building to include minimal finish materials to limit the demand on virgin resources.

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BIOGRAPHICAL SKETCH

David Roberts was born in 1986. After being raised in Altamonte Springs, FL, he attended Florida State University and earned a Bachelor of Science degree from the College of Business in management. Having worked for both a building and roofing contractor, he applied to graduate school at the M.E. Rinker, Sr. School for Building Construction at the University of Florida. He received his M.S.B.C. degree in the fall of 2009 and has since pursued career opportunities in construction management.