BIOBASED PRODUCTS AND THE LEED® RATING SYSTEM

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INTRODUCTION

At the beginning of the 20th century, over 40% by weight of all the materials consumed through the production of goods within the United States were comprised of renewable resources (Matos and Wagner 1998). In contrast, by the end of the 20th century renewable material usage had dropped to less than 8% by weight (Matos and Wagner 1998). Combined with both an increase in the overall rate at which we consume resources as well as growing awareness of the inherently finite availability of nonrenewable resources, the early decades of the 21st century may mark the beginning of a shift back to an increased use of biobased materials. While the relative proportion of the demand for biobased materials has changed over the past century, one factor that has remained constant is that a majority of renewable and nonrenewable resources consumed in the U.S. is used in the construction industry (Matos and Wagner 1998).

Although the utilization of biobased products is increasing throughout all sectors, their popularity still lags in the building and construction industry, and they are surpassed by more widely accepted green practices such as the use of pre- and post-consumer recycled materials. There is, however, a great potential benefit to be gained from a resurgence in the use of biobased products, both from general environmental and human health perspectives. Examples of specific sectors that may profit from this include building and construction industries, which account for 40% (Roodman and Lenssen 1995) of global raw material usage, as well as the Federal government, which is the largest real property owner in the U.S. (U.S. General Services Administration 2006).

A biobased material is defined as containing some percentage of a biologically renewable resource. According to ASTM E2114-2004, a renewable resource is something "that is grown, naturally replenished, or cleansed, at a rate which exceeds depletion of the usable supply of that resource." The length of time needed to replace a renewable resource can vary greatly depending upon the resource—for example, it can take 30–100 years for a tree to mature while bamboo can be harvested in as little as 7 years. Rapidly renewable resources are defined, for the purposes of this paper, as those that can be replaced within 10 years. Bamboo, linoleum, and cork are just a few of the more common examples of rapidly renewable resources.

The renewable, biobased, component of a material is either derived from a plant or animal, and resource supplies are typically managed in a sustainable fashion, thus ensuring its continued availability. This material may then be used within the product in a fairly unaltered state, it may undergo some chemical or physical transformation, or it may be combined with other products to create an intermediate ingredient in the production or manufacturing process.

The decrease in biobased material utilization over the last 100 years has led to an increased use of non-biobased materials, and this development can yield numerous potentially negative impacts that have been fairly well documented in terms of many of their environmental impacts such as eutrophication and air pollution. These, however, only account for a portion of the total sum of potential impacts. In addition to potentially harmful impacts on the exterior environment, various material ingredients and components can negatively affect the interior environment as well through the release of volatile organic compounds (VOCs) and other types of indoor air pollutants. VOCs are a concern because their emissions can be an ongoing problem within an interior space, since in addition to the initial release of compounds, surfaces can continually absorb and re-release the compounds back into the environment where they are absorbed by the inhabitants. If this occurs in combination with other problems, like poor building air circulation, the potential can develop for more serious concerns such as "Sick Building Syndrome" (U.S. Environmental Protection Agency 2010). While some of this can be mitigated through improved ventilation, indoor air quality is still found to be a concern by the U.S. Environmental Protection Agency (Indoor Air Quality, 2010) and other groups.

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One of the most well known indoor air contaminants is formaldehyde, which is commonly found in the adhesives used in pressed wood products such as furniture, shelving, or particleboard; finishes and coatings on fabrics; paints and coatings; as well as some types of insulation.[3] A 2008 study by Papadopoula, Nakos, and Tsiantzi examined the replacement of the formaldehyde-based resins with certain renewably based ones that yielded equivalent, and in some cases superior, performance characteristics in addition to providing a reduction in VOC levels. Another study that investigated school cleaning products found that, on average, the contaminate emission rate for green general cleaners was one fifth that of conventional cleaners (Environmental Working Group 2009). Other studies too, have shown correlations between the use of petroleum-based products and increased VOC levels.

A joint report by the Healthy Building Network and Health Care Without Harm (Silas, Hansen, and Lent, 2007) also promotes the use of renewable materials to lessen indoor air quality concerns, and it provides guidelines and information for the health care industry on the benefits of renewable and biobased materials as well as the potential issues associated with petrochemical-based fibers. Additionally, the Healthy Building Network offers biopolymer and bioplastic production and purchasing guidelines.

These environmental and health related concerns, as well as the potential market for biobased products, have become the focus of a variety of different areas of legislation and development. In addition to numerous Federal initiatives, an increased awareness of biobased materials and products is also being fostered within the building and construction fields by building rating systems such as Energy Star®, Green Globes, and Leadership in Energy and Environmental Design (LEED®).

KEYWORDS

biobased, rapidly renewable, Federal initiatives, BioPreferred, LEED, building products, sustainability

BACKGROUND

Legislation and Biobased Development

Part of the impetus for resurgence in the use of renewable resources has come from the Federal government through several different programs and initiatives. One of the earliest Federal initiatives was *The Biomass Research and Development Act of 2000* (Biomass Research and Development Act of 2000 § 302,7 USC 8601, 2000) that laid the groundwork for later developments pertaining to biobased products. This law highlighted some of the potential benefits afforded by the increased usage of biobased feedstocks, chemicals, and products. One of the benefits noted was the potential for improved environmental quality due to the potentially less hazardous nature of biobased products as well as the opportunity for reduced greenhouse gas emissions (predominately CO_2) from the decreased use of fossil-fuel-based materials and components. Along with these positive environmental attributes, another benefit to the use of biobased products is their potential for sustainability, since they are derived, at least in part, from renewable resources. Further reaching benefits of the transition to a more biobased economy, as found in a study conducted by the Institute for Agricultural and Trade Policy (Cultivating a New Rural Economy: Assessing the Potential of Minnesota's Bioindustrial Sector 2005), include the opportunity to create new jobs in a variety of fields as well as stimulate rural economic development.

The next major step in the push toward increased biobased development came in 2002 with the *Farm Security and Rural Investment Act*. This legislation contains two items of particular importance to advance the biobased industry. Within it, the Federal government defines a biobased product as:

> A product determined by the Secretary to be a commercial or industrial product (other than food or feed) that is composed, in whole or in significant part, of biological products or renewable domestic agricultural materials (including plant, animal, and marine materials) or forestry materials. (Farm Security and Rural Investment Act of 2002 § 9001,7 USC 8101, 2002)

One of the most important items in this Act, at least for the purposes of this article, was the establishment of a Federal procurement program for biobased products originally referred to as the Federal

Biobased Products Preferred Procurement Program (FB4P). This program requires all Federal agencies, and those contracted by them, to purchase biobased products in cases where the following criteria apply:

> Each Federal agency shall comply with the requirements set forth in this section and any regulations issued under this section, with respect to any purchase or acquisition of a procurement item where the purchase price of the item exceeds $10,000 or where the quantity of such items or of functionally equivalent items purchased or acquired in the course of the preceding fiscal year was $10,000 or more. (Farm Security and Rural Investment Act of 2002 § 9001,7 USC 8101, 2002)

Additionally, to be subject to preferred procurement, these products must also be available within a reasonable timeframe, meet the performance standards of both the specifying agency and any other applicable standards and codes, as well as be competitively priced with other, similar, non-biobased products.

Further refinement of this program came about with the *Food, Conservation, and Energy Act of 2008*. (Food, Conservation, and Energy Act of 2008 § 9001, 2008) In addition to renaming the procurement program the Biobased Markets Program, this bill includes intermediate ingredients and feedstocks within the definition of a biobased product. It also outlines the process used to determine their eligibility within the program; and, finally, it proposed a rule establishing qualification criteria by which products can receive the "USDA Certified Biobased Product" label via the voluntary labeling program.

The Biobased Markets Program, now called the BioPreferred Program, focuses on a number of different categories, with more categories and products being added annually. A majority of these categories focuses on components and products relating to the building and construction industries as well as existing building maintenance and operations. Not all of the following product categories have been officially designated and may be subject to change; the list found in Table 1 is intended to illustrate the potential breadth of products covered by this program.

Other Federal developments outside the aforementioned legislation have also increased the potential adoption of biobased products. One of the more influential of these is *Executive Order 13423—Strengthening Federal Environmental, Energy, and Transportation Management,* (2007) which outlines a number of policies aimed at improving environmental, energy, and transportation performance and standards within Federal agencies. Within this executive order, several different goals support the use

TABLE 1. Potential and Officially Designated USDA BioPreferred Product Categories (U.S. Department of Agriculture, 2010).

Product Category (Items in **Bold** have been officially designated by the USDA)
Asphalt and Tar Removers
Asphalt Restorers
Bedding, Blankets, and Linens **Bedding, Bed Linens, and Towels**
Biodegradable Foams including: Insulation Acoustical/Soundproofing foam Furniture Components
Cleaning Products and Supplies Floor Cleaners and Protectors Furniture Cleaners and Protectors Multipurpose Cleaners
Composite Panels including: **Acoustical** **Interior** **Plastic Lumber** **Structural Interior and Wall**
Concrete and Asphalt Release Fluid
Complex Assemblies Furniture
Floor Coverings including: **Carpet** Hard Surface Flooring
Mulch and Compost
Paints and Coatings including Interior Paint Wood and Concrete Stains
Spray Insulating Foams
Roof Coatings
Wood and Concrete Sealers **Membrane** **Penetrating**

of biobased products: *Section 2.e.i* encourages the reduction of toxic and hazardous chemical usage; *Section 2.d* provides guidelines for new construction and major renovation of agency buildings through the Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings set forth in the Federal Leadership in High Performance and Sustainable Buildings Memorandum of Understanding [MOU] (2006). Signed by representatives from 16 federal agencies, this provides guidance for the achievement of better performing and more sustainable development within new construction and renovations undertaken by Federal agencies. Although the Guiding Principles do not endorse any specific building rating system, they do note that projects that registered for Leadership in Energy and Environmental Design (LEED®) certification prior to October of 2008 will be considered to have met the Guiding Principles, although this may not be the case for all projects registered after this date due to differences in the requirements of each respective organization. In order to assist with determining if a project meets these guidelines, the Department of Energy has created a checklist (U.S. Department of Energy 2010) that lists all available LEED® credits paired with the corresponding Guiding Principle. According to this checklist, the LEED® credits pertaining to Rapidly Renewable Materials as well as the majority of those credits pertaining to the use of Low-Emitting products are required under the Guiding Principles. Other agencies have also created similar checklists and many of these make specific reference to LEED® credits or certification as well.

GENERAL INTRODUCTION TO THE LEED® RATING SYSTEMS

Structure

LEED® is comprised of a group of different rating systems (based on type of building and type of construction) that promotes more environmentally responsible buildings through the awarding of points within a variety of general categories including: Site Selection, Water Efficiency, Energy and Atmosphere, Indoor Environmental Quality, Materials and Resources, Innovation in Design, and Regional Priority Credits. Additionally, credits can also be obtained for exceeding the requirements of certain credits, which are denoted as being eligible for Exemplary Performance credit.

Site Selection

This section focuses on steps that can be taken to minimize environmental impacts before, during, and after construction. Some of the more heavily weighted credits deal with site selection as it relates to the surrounding community and the reduction of personal automobile use through the accessibility to alternate forms of transportation. Site development, stormwater design, the heat island effect, and the reduction of light pollution are also addressed in this section.

Water Efficiency

This area provides guidelines for practices and approaches that can minimize water usage. Within the broader category of water efficiency, strategies are addressed for water use reduction both within the building as well as outside. Various uses of greywater are also found here as well.

Energy and Atmosphere

One of the most heavily weighted portions of LEED®; this section focuses on ways to reduce energy use and also promotes the use of alternate energy sources. Credits in this category deal with items like commissioning, energy performance, and renewable energy usage.

Materials and Resources

This topic covers a range of issues including recycling, building reuse, construction waste, material reuse, and material selection.

Indoor Environmental Quality

There are a few main categories in this section that address a range of interior issues. These include indoor air quality, thermal comfort, and the use of daylighting within the space.

Innovation in Design

Going beyond the requirements of any of the aforementioned topics or using an approach that is not addressed in any other credit may gain a point in this section, which is also referred to as Exemplary Performance.

Regional Bonus Credits

These credits are designed to address more specific regional factors based on project location.

Scoring

In order to achieve LEED® certification, a building must obtain a certain number of points. A breakdown of this is outlined in Table 2.

Depending upon the type of construction or renovation being undertaken, one of a number of different LEED® rating systems may apply. Each of these has a slightly different weighting of available points, and within each of these subsets the potential role of biobased products varies in regard to both relative size and scope. In order to provide a comprehensive overview of biobased products with Federal and governmental agencies, it is necessary to examine a few different rating systems to most effectively illustrate the numerous potential impacts biobased products can have on both the interior and exterior environments.

LEED® for New Construction (NC), which encompasses both new construction as well as major renovation, is most applicable for commercial and institutional spaces. For more speculatively developed properties, such as those planning to lease spaces to future tenants, LEED® for Core and Shell (CS) would be ideal since it addresses only the "base building elements" that include the building's structure, exterior envelope, and mechanical systems such as HVAC. For future tenants of these spaces the LEED® for Commercial Interiors rating system is commonly used since it allows for the achievement of certification based upon those elements more directly under tenant control and, if applicable, also recognizes green improvements made to the existing building. For older buildings, LEED® certification is available also in the form of LEED® for Existing Buildings (EB), which focuses primarily on the maintenance and operations of the space. LEED® EB can also be awarded to those buildings and spaces previously awarded certification under a different rating system.

TABLE 2. LEED® Points Breakdown

100 Total Possible Points (+ 10 Bonus Points depending on rating system)	
LEED® Certified	40–49 Points[4]
LEED® Certified Silver	50–59 Points
LEED® Certified Gold	60–79 Points
LEED® Certified Platinum	80–110 Points

Among the several other green building standards currently in use, there exists at least one that explicitly advances the goal for increased use of biobased materials in buildings. It is the Swiss-based Minergie-Eco/Minergie-P-Eco standard, which, as an expansion of the basic Minergie standard, includes in the evaluation of buildings not only energy efficiency but also the building ecology (in German *Bauökologie*), i.e., the ready availability of raw products and their high content of recyclable materials; building products with low environmental impact during their production and processing (embodied energy); and the simplicity with which buildings can be built back, that is, recycled after their useful life, while preserving the environment.[5] All the above characteristics and applications distinguish, of course, biobased materials from petrochemical products. One specific example for a large-scale shift from fossil-fuel-based to biobased materials is the use of building insulation. Until fairly recently foamed insulation sprayed into wall and ceiling cavities always used petrochemical components but now soy-based foam insulation is readily available. From an embodied energy and recyclability perspective mineral wool and cellulose materials are even better alternatives than foam. Cellulose specifically is one of the most useful materials in building construction and retrofitting of old buildings. It has the highest recycled content of any commonly available insulation material (up to 85%, in contrast to fiberglass insulation which has up to 40% recycled content), and it also has much less embodied energy (up to 10 times less) than fiberglass and other furnace-produced mineral insulations.[6]

In terms of resources, another comprehensive place for information about sustainable building, and by implication biobased materials, is the consortium Architecture 2030.[7] More specifically, the section on building materials provides a table of materials and their embodied energy.[8] Of course, it would be useful to develop a materials database that would allow anyone in the building industry to compare petrochemical and biobased materials from a quantitative perspective.

APPROACH

In order to ascertain the level of adoption and impact of biobased products the available data regarding applicable credit achievement within the LEED® rating system by certified Federal agency projects was reviewed. Although neither the United States Green Building Council, which oversees the LEED® rating system, nor the Green Building Certification Institute, which is responsible for LEED® building certification, has statistics available regarding achievements of specific credits such as those pertaining to the use of biobased materials, there are numerous case studies and overviews of LEED® certified government buildings available, which can allow general trends to be established.

FINDINGS

LEED® Adoption by Federal Agencies

The impact of the aforementioned Federal initiatives, recommendations, and legislation is reflected in the percentage of government owned or occupied LEED® buildings; as of April 15, 2010, nearly 30% of LEED® projects were owned or occupied by Federal, state, or local governmental entities. Of these, the Federal government is responsible for 221 certified projects with an additional 3349 registered projects pursing certification. (U.S. Green Building Council 2010) Influenced in part by Federal legislation, virtually every executive department now has some legislation in place that mandates or recommends certification through the LEED® rating system.

While no building rating system is perfect, LEED® has become the most popular both in the private and public sectors—a popularity that is reflected within the increasing number of Federal, state, and local agencies adopting it in some measure. As of May 1, 2010, LEED® initiatives could be found in 14 Federal agencies or departments, 34 state governments, and over 200 cities, counties, and towns (U.S. Green Building Council 2010). Table 3 outlines some of the LEED® initiatives undertaken by Federal departments and agencies; those in **bold** denote signers of the Sustainable Buildings MOU.

As data from both the USGBC and Agency websites show, the use of the LEED® rating system is increasing among governmental agencies. The Government Services Agency (GSA), which oversees a large percentage of government buildings and real estate, is one of the most active and was also the first Federal agency to join the USGBC. Since 2003, the GSA has required that all capital building projects and leased construction meet LEED® Silver certification (Minimum performance criteria for recovery projects 2010). As of April 2008, the GSA had 25 certified buildings and 75 registered projects; by December of 2009, these numbers had grown to 45 certified projects and 181 registered (GSA LEED statistics 2009). Other agencies responsible for a very large number of certified and registered LEED® projects include the Department of Defense and the Department of Energy.

Although the numbers of LEED® registered and certified projects may seem indicative of widespread adoption of green building practices and materials, the relative percentage of those receiving credit for the use of biobased or rapidly renewable products is relatively low. In fact, of those projects for which credit information is available, only a few had achieved credit for the use of rapidly renewable products, which is one of the credits most strongly tied to biobased products. This trend is not limited to just Federal projects. A recent study by J. Yudelson found that "Rapidly renewable materials such as cork and bamboo flooring are used only in 28% of Platinum projects versus less than 5% of other projects." (Yudelson 2009) Certified wood, this same study found, was a more commonly achieved credit, with 48% of Platinum projects and 42% of Gold receiving credit for its use. Another study, which compared credit achievements between Canada and the U.S, found a greater percentage of use of both rapidly renewable material and certified wood among Gold and Platinum rated projects (Da Silva and Ruwanpura 2009). The authors of the credit comparison study also cite difficulty with availability as one of the factors hindering increased credit achievement in these areas in Canada. Biobased products, as noted above, can also assist with achievement of credits pertaining to indoor environmental quality, a category that includes some of the most frequently achieved credits—in fact, this same study noted achievement rates between 85–100% for some credits. A more comprehensive breakdown of the results of this study is shown in Table 4.

TABLE 3. Examples of LEED® Initiatives Undertaken by Federal Departments and Agencies.

Department or Agency	Certification Level and Applicable Projects
Department of Agriculture (USDA)	Promotes LEED® Silver for New Construction/Major Renovation (Sustainable buildings implementation plan, 2007)
	Forest Service: Requires LEED® Silver for new construction 10,000 sq. ft. or greater (FSH 7309.11 Buildings and Related Facilities Handbook, 2008)
Department of Defense (DOD) *(The Navy was the first federal agency to certify a LEED® project)*	U.S. Air Force: Encourages LEED® for New Construction/Major Renovation for MILCON projects *(Air Force Sustainable Design and Development Policy)*
	U.S. Army: Requires meeting requirements for LEED® Silver for "All new vertical construction," and LEED® Certified requirements for projects certified under LEED® EB also considering adoption of LEED® for Homes (U.S. Army sustainability: Leadership in energy and environmental design, 2007)
	U.S. Navy: Requires LEED® Silver for all applicable projects (NAVFAC engineering and construction bulletin 2007)
Dept of Energy (DOE) *(Supported development of LEED®)*	Requires LEED® Gold for all new CD-1 or lower buildings of over $5M, and preference to LEED® Gold when selecting new leased space. (Departmental Energy, Renewable Energy and Transportation Management, 2008)
U.S. Environmental Protection Agency (EPA)	Requires LEED® Gold for all new construction and building acquisition projects over 20,000 sf. (EPA Facilities Manual, Volume 2 – Architecture and Engineering Guidelines, 2006)
Dept of Health and Human Services (HHS)	Requires LEED® or Green Globes certification for all construction projects with total cost equal or greater than $1million and repair and maintenance of existing facilities with total project cost of equal or greater than $3 million. (Going green in 2007: An overview of new requirements for sustainable facility design and construction, 2007)
Department of the Interior (DOI)	LEED® Certified or one Green Globe. All new construction and major renovation building projects with gross construction costs greater than $2,000,000. (Department of Interior Sustainable Buildings Impementation Plan)
Department of Justice (DOJ)	"DOJ's current policy is to use LEED® Silver as an agency goal for all new construction projects" (Interagency Sustainability Working Group, 2006)
Department of Labor (DOL)	"In addition, Job Corps will aggressively pursue opportunities to improve the sustainability of its facilities, particularly through energy retrofits, building designs incorporating Leadership in Energy and Environmental Design (LEED®) principles, and the development of alternative energy sources." (U.S. Job Corps [U.S. Department of Labor])

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TABLE 3. *(continued)*

Department or Agency	Certification Level and Applicable Projects
Department of State (DOS)	Committed to using LEED® on the construction of 180 new embassies worldwide over the next 10 years "As LEED® certification has become a coveted symbol of environmental responsibility, the Bureau has required all future U.S. Embassies to earn this certification." (LEED certified Embassies: Embassies go green 2010)
Department of Veterans Affairs (VA)	Requires meeting LEED® New Construction or Commercial Interiors standards for "all stand alone buildings, substantial renovations, and other work as applicable (e.g., acute care, long-term care, new office buildings, build to suit lease projects, cemetery buildings and grounds, etc.)." "For VA lease projects, the evaluation of proposals should give additional points to those facilities that have a LEED® rating, and the number of points should be scaled to the successive LEED® levels." (Federal Mandates Mapped to LEED)
General Services Administration (One of LEED's earliest adopters)	Requires LEED® Silver, encouraged to achieve LEED® Gold for all capital building projects and lease construction. (Sustainable design program, 2010)
National Aeronautics and Space Administration	Requires LEED® Silver, encourages LEED® Gold for new construction and renovations of NASA facilities projects (This LEED® goal will be reviewed, renewed, or changed every 3 years) (NASA goes green: New Marshall Center building earns environmental distinction 2006)

TABLE 4. Credit Comparison Between Canada and U.S.

	Certification Level					
	Certified		Silver		Gold/Platinum	
Credit	Canada (%)	U.S. (%)	Canada (%)	U.S. (%)	Canada (%)	U.S. (%)
EQ 4.1 (Low Emitting Materials—Adhesives and Sealants)	88	100	73	100	79	100
EQ 4.2 (Low Emitting Materials—Paints and Coatings)	75	95	87	94	84	100
EQ 4.3 (Low Emitting Materials—Flooring Systems)	88	92	87	100	95	100
EQ 4.4 (Low Emitting Materials—Composite Wood and Agrifiber Products)	13	42	60	75	63	100
MR 6 (Rapidly Renewable)	0	9	7	6	5	50
MR 7 (Certified Wood)	13	32	7	44	5	50

Within the various LEED® rating systems there is the potential for biobased products to play a significantly larger role, leading to an increase in the overall use of biobased product and could also contribute to the achievement of numerous other credits that form the basis of the rating system.

POTENTIAL BIOBASED RELEVANT LEED® CREDITS

LEED® 2009 for New Construction (NC) and Major Renovation (MR)

Both new construction and major renovation represent a big potential for biobased products integration. According to the Architecture2030 report, the total U.S. building stock equals approximately 300 billion square feet. According to the 2008 Federal Real Property Report, the Federal government owns or leases about "896,000 buildings and structures with a total area of 3.29 billion square feet" and some 354 million square feet of this property is held by the GSA (GSA property overview 2010). Every year 1.75 billion square feet of the total national building stock is demolished, and about 5 billion square feet is renovated, while an equal amount (5 billion square feet) is newly built. In addition, biobased products can contribute, either directly or indirectly, 8 points or more toward LEED® NC certification, which accounts for at least 20% of the 40 point minimum required for LEED® NC: Certified status.

Materials and Resources

MR Credit 6: Rapidly Renewable Materials—1 Point

(Also eligible for 1 point Exemplary Performance) (LEED reference guide for green building design and construction 2009, pp. 387–392)

This credit is the only credit that focuses directly on the usage of short-cycle biobased materials within the LEED® NC rating system. In this case, a distinction is made between different types of renewable resources; rapidly renewable (or short-cycle) being resources with a harvest or regeneration rate of 10 years or less, and long-cycle having a rate greater than 10 years. While all rapidly renewable resources are biobased, not all biobased materials are rapidly renewable—materials such as wood exemplify this, having typical harvest rates of 30 years or longer.

As defined by the U.S. Green Building Council for the purposes of LEED®:

> Rapidly renewable materials are considered to be an agricultural product, both fiber and animal that takes 10 years or less to grow or raise, and to harvest in an ongoing and sustainable fashion. (LEED reference guide for green building design and construction 2009, pp. 392)

Within the LEED® reference guide, noted examples of such products include various types of hard, resilient, and soft surface flooring, panels and plywood, insulation, geotextile fabrics, and form-release agents. Biobased products, including many made in part of rapidly renewable resources, in these and numerous other product categories can be found both in various print and online databases, the USDA's BioPreferred Catalog (http://www.catalog.biopreferred.gov) is an example of one such source. As is true with the decision to implement LEED® in general, the decision to attempt this credit needs to be made early in the design process, since its achievement is closely linked to the allocation of the materials portion of the total project budget.

The successful achievement of this credit is based on meeting or exceeding a percentage of the total cost of all project materials (in this case, 2.5%) through the use of rapidly renewable finishes, furnishings, and construction materials and other products. While this calculation is fairly straightforward, complexities can arise when dealing with assembled components such as office workstations, of which only certain elements are constructed of rapidly renewable materials. Achieving 5% will yield 1 extra point for exemplary performance.

The Weather Forecast Office[9] in Caribou, ME is one example of a Federal building that has met the requirements of MR Credit 6 through the use of rapidly-renewable acoustical ceiling tiles, and pressed strawboard was utilized in all built-in cabinetry in the building. The use of materials such as the agrifiber board also most likely contributed to at least one of the four points the building achieved for the use of low-emitting materials.

The Center for Immigration Services,[10] Nebraska Service Center in Lincoln, NE is another example—in this case, rapidly renewable materials accounted for nearly 8.5% of the total project value and, as with the project above, also received four points for the use of low-emitting materials.

Materials and Resources Credit 7: Certified Wood—1 Point

(Also eligible for 1 point Exemplary Performance)
(LEED reference guide for green building design and construction 2009, pp. 393–400)

This credit, as its name implies, focuses on the use of FSC certified wood in LEED® projects. Although not technically wood, a 2009 ruling by the USGBC states that certified bamboo can be applied to both Material and Resources Credits 6 and 7. (Materials & Resources: certified wood 2009) The Forest Stewardship Council, which is responsible for developing sustainable forestry standards, also certifies both forests and forestry products to ensure that the forests are responsibly managed. The percentage of FSC certified wood that needs to meet the requirements of this credit is 50% (as measured by cost). The achievement of MR Credit 7 requires verification of FSC certification in the form of Chain of Custody certification.

Some notable Federal projects that have achieved MR Credit 7 include the EPA Region 8 Headquarters in Denver, CO and Potomac Yards 1 and 2 in Arlington, VA.[11] The EPA Headquarters, a LEED® Gold building, used over 89% FSC certified wood, in addition to also using some rapidly renewable materials as well as achieving credit for three of the four credits relating to low-emitting materials. Also performing well with respect to FSC certified wood, the Potomac Yards[12] utilized 83% certified wood in addition to achieving all four of the low-emitting material related credits.

Indoor Environmental Quality—4 Points Total

(LEED® reference guide for green building design and construction 2009, pp. 401–583)

Indoor air and environmental quality issues are the focus of 17 of the 110 maximum total points within LEED® BD&C. Of these, the use of rapidly renewable materials can potentially contribute to the achievement of 4 of these points. The reduction of the level of indoor air contaminants within the interior of the building is the main goal of the Indoor Environmental Quality Credits 4.1 through 4.6. The last two credits, 4.5 and 4.6, are available only to school projects though the maximum credit achievement within IEQ 4 remains 4 points total. The achievement requirements for schools do differ somewhat from those of other buildings, and will not be addressed here.[13] Each credit within this section focuses on a different element of the interior environment:

- IEQ 4.1: Low Emitting Materials—Adhesives and Sealants
- IEQ 4.2: Low Emitting Materials—Paints and Coatings
- IEQ 4.3: Low Emitting Materials—Flooring Systems
- IEQ 4.4: Low Emitting Materials—Composite Wood and Agrifiber Products
- IEQ 4.5: Low Emitting Materials—Systems Furniture and Seating (Schools Only)
- IEQ 4.6: Low Emitting Materials—Ceiling and Wall Systems (Schools Only)

IEQ Credit 4.1: Low-Emitting Materials – Adhesives and Sealants—1 Point

(LEED reference guide for green building design and construction 2009, pp. 471–480)

This credit applies to all sealants and adhesives used within the interior of the building, encompassing everything "inside of the weatherproofing system and applied on-site" (p. 471). To meet the requirements for this credit, products must be within the Volatile Organic Compound (VOC) limits set for each product category. All adhesives, sealant primers, and sealants shall meet South Coast Air Management District (SCAQMD) Rule 1168 while all aerosol adhesives must meet Green Seal Standard for Commercial Adhesives GS-36. SCAQMD Rule 1168 aims to reduce VOC emissions as well as eliminate chloroform, ethylene dichloride, methylene chloride, perchloroethylene, and trichloroethylene emissions from adhesives, sealants, and sealant primers. Additionally, it provides definitions of all applicable terms and products as well as all necessary calculations and limits to VOC levels for a wide range

of adhesive, sealant, and sealant primer product categories. Similar to the goals of Rule 1168, Green Seal Standard GS-36 aims to limit the VOC levels found in aerosol and non-aerosol adhesives. Due to stricter regulations for non-aerosol adhesives in Rule 1168, only those requirements for aerosol adhesives are applicable for successful completion of this credit.

The credit is successfully achieved if all adhesives and sealants comply with their respective requirements. In instances where the VOC level for a product exceeds that of the SCAQMD/Green Seal level, as in the case of unintentional usage, then the credit still may be achieved by calculating the total VOC levels of all products used and comparing it to the total levels specified by SCAQMD/Green Seal. If the project's VOC levels are lower than the credit, it is still successfully achieved.

IEQ Credit 4.2: Low-Emitting Materials – Paints and Coatings—1 Point
(LEED reference guide for green building design and construction, 2009, pp. 481–486)

The goal of this credit is much the same as that of IEQ 4.1, although it focuses on the paints and other coatings used within the space. Three main standards apply to this credit: Green Seal Standard GS-11 applies to VOC level limits in architectural paints and coatings; GC-03 regulates the VOC levels in anti-corrosive and anti-rust paints; and SCAQMD Rule 1113 pertains to VOC limits in clear wood finishes, stains, and floor coatings. As with the previous credit, compliance with the aforementioned criteria results in successful achievement as does not exceeding the total specified VOC levels as outlined by the referenced standards.

IEQ Credit 4.3: Low Emitting Materials – Flooring Systems—1 Point
(LEED reference guide for green building design and construction 2009, pp. 487–489)

As with the other IEQ credits outlined above the main focus of this credit is on the reduction of indoor air contamination, in this case through the use of low emitting flooring and floor adhesives. Both soft and hard floor coverings are addressed within this credit, with a number of different applicable rules and VOC level requirements depending upon the type of flooring being used in the space. Soft floor coverings like carpet and carpet pads must meet Carpet and Rug Institute's (CRI) Green Label Plus and Green Label requirements, respectively. The CRI requirements, as with the various other standards referenced here, focus on low VOC emitting products. The carpet adhesive must also adhere to the VOC levels outlined in IEQ 4.1. Hard surface floor coverings including wood, vinyl, ceramic, and linoleum, must be FloorScore compliant. Developed by the Resilient Floor Covering Institute and Scientific Certification Systems, FloorScore is a testing and certification system that measures a product's compliance with various California indoor-air-quality VOC emission requirements. Floor finishes are covered under this credit well, with VOC limits being set by SCAQMD 1113 as described in IEQ 4.2. A final set of requirements is outlined in SCAQMD Rule 1168, as referred to in IEQ 4.1, which applies to tile grout and adhesives.

IEQ Credit 4.4: Low-Emitting Materials – Composite Wood and Agrifiber Products—1 Point
(LEED reference guide for green building design and construction 2009, pp. 495–500)

Similar to the credits listed above, this credit addresses indoor air quality as it pertains to agrifiber and composite wood products used within the building's interior. This credit does not, however, include any fixtures, furnishings, or equipment within the space. Agrifiber and composite products have numerous uses within the built environment with applications ranging from furniture (which may not be applicable for this credit), acoustical tiles, and structural insulated panels. For successful completion of this credit, applicable elements must not contain any added urea-formaldehyde resin—a substance that the EPA considers potentially carcinogenic (An Introduction to Indoor Air Quality: Formaldehyde).

IEQ Credit 4.5: Low Emitting Materials – Systems Furniture and Seating—1 Point

IEQ Credit 4.6: Low Emitting Materials – Ceiling and Wall Systems—1 Point
These credits are only relevant to school projects and offer a few different options for successful achievement. The requirements for Credit 4.5 cover all

classroom furniture that was refurbished or manufactured within one year prior to occupancy while furniture older than this is excluded. Credit 4.6, as its name implies, looks at ceiling and wall systems, including gypsum board, insulation, and wall coverings, installed throughout the space. More information regarding these credits can be found in the LEED® Reference Guide for Green Building Design and Construction, 2009 Edition.

Given the proportionately high number of projects that successfully achieve one, or more often, several of the Low Emitting Materials credits, there are numerous examples of Federal projects that exemplify the goals of this set of credits. One particularly interesting project is the National Renewable Energy Laboratory's Science and Technology Facility[14] that achieved all four IEQ Low Emitting Credits in addition to being the first LEED® Platinum Federal building.

Other Potential Credits

In addition to the more directly applicable credits, biobased products may also contribute to the achievement of a few other points toward certification such as MR5: Regional Material Credit (1 point) for products that are grown and manufactured within a 500 mile radius (this would make it possible for many feedstock growing regions in the United States to supply many materials that would meet the MR5 credit) or RP1: Regional Priority Credit (1–4 points) which awards additional points contingent on specific credit achievement based upon geographic location. While not necessarily based upon renewable content, countless other credits offer opportunities for the incorporation of biobased products (the use of a locally produced biobased acoustical ceiling tile, for example, may contribute to the achievement of credits pertaining not only to rapidly renewable, but also acoustical performance, low emitting materials, regional materials, and even thermal comfort).

LEED® 2009 for Commercial Interiors (CI)

(LEED reference guide for green interior design and construction 2009)

Biobased products can potentially contribute, either directly or indirectly, 9 points or more toward LEED® CI certification, which accounts for over 22% of the 40 point minimum required for LEED® CI: Certified status. Because the biobased applicable credits within this rating system are similar in aim and achievement criteria to those in New Construction, they are simply listed below for reference. For more information on these credits, please refer to the LEED® Reference Guide for Green Interior Design and Construction, 2009 Edition.

Materials and Resources

- MR Credit 6: Rapidly Renewable Materials (pp. 259–266)—1 Point + 1 Exemplary Performance
- MR Credit 7: Certified Wood (pp. 267–276)—1 Point + 1 Exemplary Performance

Indoor Environmental Quality

- IEQ Credit 4.1: Low Emitting Materials – Adhesives and Sealants (pp. 331–336)—1 Point
- IEQ Credit 4.2: Low Emitting Materials – Paints and Coatings (pp. 337–342)—1 Point
- IEQ Credit 4.3: Low Emitting Materials – Flooring Systems (pp. 343–348)—1 Point
- IEQ Credit 4.4: Low Emitting Materials – Composite Wood and Agrifiber Products (pp. 349–352)—1 Point
- IEQ Credit 4.5: Low Emitting Materials – Systems Furniture and Seating (pp. 353–358)—1 Point (In this rating system, Credit 4.5 is applicable to all projects)
- Other potential credits include those noted under New Construction

LEED® 2009 for Existing Buildings: Operations and Maintenance (O&M)

(LEED reference guide for green building operations and maintenance 2009)

Unlike the previous rating systems that focus primarily on new construction and renovation, LEED® O&M focuses on the improvements that can be made to existing spaces. Biobased products can potentially contribute, either directly or indirectly, 6 points or more toward LEED® EB certification, which accounts for at least 15% of the 40 point minimum required for LEED® EB: Certified status.

Materials and Resources, Credit 1: Sustainable Purchasing – Ongoing Consumables—1 Point
(Also eligible for 1 point Exemplary Performance)
(LEED reference guide for green building operations and maintenance 2009, pp. 251–258)

This credit focuses on ongoing consumables, which include frequently used items such as toner cartridges, paper, binders, and desk accessories. While there are a number of different criteria that a product can meet to achieve this credit, there are two options that can potentially be met through the use of biobased products. The first criterion specifies at least 50% rapidly renewable content and the second calls for at least 50% FSC certified wood. Successful achievement of this credit is based upon cost, with sustainable purchases to meet or exceed 60% of the total purchases by cost of ongoing consumables. Additionally, if a product qualifies for more than one of the criteria, then its respective cost can be counted once for each criterion met.

MR Credit 2: Sustainable Purchasing – Durable Goods—1–2 Points
(Also eligible for 1 point Exemplary Performance)
(LEED reference guide for green building operations and maintenance 2009, pp. 259–268)

Similar to MR Credit 1, this credit also focuses on sustainable purchasing practices although the focus here is on higher priced, less frequently purchased items. There are two methods to receive points for this credit. One point can be gained through the purchase of Energy Star® or electric powered equipment. More relevant to biobased products, the second way to achieve this credit is through sustainable furniture purchasing. As with MR Credit 1, there are two potential criteria from the multiple options that can be met to achieve this credit. The same percentage requirements found in MR Credit 1 also dictate these criteria as well in regard to biobased products: one option specifies 50% rapidly renewable while the other calls for 50% FSC certified wood. In this credit as well, qualification for more than one criterion allows the cost to be counted once per each criteria met.

MR Credit 3: Sustainable Purchasing – Facility Alterations and Additions—1 Point
(Also eligible for 1 point Exemplary Performance)
(LEED reference guide for green building operations and maintenance 2009, pp. 269–282)

As with MR Credits 1 and 2, Credit 3 focuses on sustainable purchasing as well—in this case, those elements associated with renovations, additions, and new construction projects. Included in this credit would be items such as composite boards, flooring, finishes, adhesives, and sealants. As with the aforementioned credits, there are multiple potential options for achievement. Depending upon which criteria apply, certain standards and certifications may be required as well: a few that are particularly relevant to biobased products include: 50% rapidly renewable content, FSC/FloorScore/CRI Green Label certified, reduced levels of VOC content, or no added urea-formaldehyde. The maximum VOC content and other requirements dictated by these standards are similar to those noted in the previous credits. Other criteria are also linked to VOC content; the allowable VOC levels for sealants and adhesives are based on SCAQMD Rule 1168 while paint and coating levels reference Green Seal's GS-11 standard. Like the other sustainable purchasing credits, products meeting more than one criterion can be applied once per criteria met. The level of sustainable purchases required for credit achievement is 50% of the total purchases by cost.

MR Credits 7 and 8: Solid Waste Management – Ongoing Consumables and Durable Goods—1 Pt
(LEED reference guide for green building operations and maintenance 2009, pp. 305–316)

While not necessarily applicable to every biobased product, purchasing biobased products that are compostable can help toward the achievement of Credits 7 and 8. Both of these credits require that 50% of their total respective waste stream be reusable, recyclable, or compostable.

IE Q Credit 3.3: Green Cleaning – Purchase of Sustainable Cleaning Products and Materials—1 Pt

(LEED reference guide for green building operations and maintenance 2009, pp. 433–438)

This credit focuses on sustainable purchasing of cleaning products and materials used by janitorial staff. Per the requirements of this credit, 30% of the total annual cost of relevant purchases must meet one or more standards that are dictated by the type of item. While there are quite a few different standards that can be met to qualify for credit achievement, all focus primarily on air quality and other environmental attributes. The main standard setting organizations within this credit are Green Seal and Environmental Choice.

Other Potential Credits

As with the other Rating Systems outlined above, the achievement of various other credits may be furthered as well through the use of biobased products.

Other Potential Developments to the LEED® Rating System

In addition to the credits found within the various rating systems, which can already potentially benefit from biobased products, there are also some proposed future changes to the LEED® rating system that may help biobased products play an even greater role. A recent white paper (Wilson 2006) to the USGBC promotes expanding Materials and Resources Credit 6: Rapidly Renewable Materials to include longer cycle renewable materials, such as wood, to allow the credit to encompass all renewable materials. Another proposal outlined in this white paper was the modification of MR Credit 7: Certified Wood to include products made from agricultural waste fibers.

CONCLUSIONS

In short, there seems to be a great deal of untapped potential regarding the contribution of biobased products within the LEED® rating system. As illustrated above, numerous LEED® credits could benefit from the selection of biobased products. The federal government alone is one of the largest owners/renters of buildings in the United States,[15] and as such has the potential to lead other government entities (local and state), as well as the building industry with exemplary building standards like LEED® that incorporate latest advances of materials research into construction guidelines. As mentioned above, other countries have successfully explored various methods of encouraging biobased material usage through both legislation and standards, including the Minergie-P-Eco standard. If the federal government were to create legislation providing a comprehensive green model for the building industry on the basis of LEED®, it would help bring not only government buildings but industrial, commercial, and residential construction up to the standard (or better) of current LEED® certified buildings. The subsequent increased usage of biobased and rapidly renewable products by federal agencies would allow for greater support of the biobased industry and could potentially allow for the achievement of higher overall LEED® ratings. The creation of a readily available, i.e., online, materials database that would allow anyone in the building industry to compare petrochemical and biobased materials from a quantitative perspective could be potentially beneficial as well. This would help producers, consumers, and building professionals make informed decisions about the increased production, specification, and potential inclusion of biobased materials in the built environment.

NOTES

3. The use of formaldehyde has already been banned by the European Union for certain uses in a directive from 1998. See http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:1998:123:0001:0063:EN:PDF, accessed December 19, 2010.
4. While the criticism has been made that the percentage of points required for LEED® Certified is disproportionately low, based upon total possible points, it does still result in some quantifiable improvements within the built environment.
5. See http://www.minergie.ch/minergie-eco.html, accessed July 13, 2010, translated from the German by Mikesch Muecke. At this point the English version of the website does not include detailed information about the –Eco and –P-Eco standards which are the ones of interest to this paper. The http://www.eco-bau.ch website also provides very useful pamphlets (sadly again only in German or French) to help builders use as many biobased materials as possible. For more information, if you read German or French, peruse the eco-BKP Merkblätter and eco-devis sections of the eco-bau website. The pamphlets give both visual and textual descriptions of preferred materials, processes, and applications.

6. See http://www.cellulose.org/CIMA/GreenFacts.php, accessed July 13, 2010.
7. See http://architecture2030.org/
8. See http://architecture2030.org/regional_solutions/materials.html, accessed July 13, 2010. This webpage also contains a link to this page, http://www.canadianarchitect.com/asf/perspectives_sustainibility/measures_of_sustainablity/measures_of_sustainablity_embodied.htm which explains in detail the ideas surrounding embodied energy.
9. More information on this specific project can be found on the Case Study section of the USGBC website (http://LEED®casestudies.usgbc.org/overview.cfm?ProjectID=334).
10. More information on this project can be found on the GSA's LEED® Case Study website (http://www.gsa.gov/Portal/gsa/ep/contentView.do?contentType=GSA_BASIC&contentId=21949).
11. More information about this project can be found on the High Performance Federal Buildings section of the U.S. Department of Energy's Federal Energy Management Program website (http://femp.buildinggreen.com/overview.cfm?projectid=864).
12. More information on this project can be found in the Case Studies section of the National Institute of Building Sciences Whole Building Design Guide website (http://www.wbdg.org/references/cs_potomac.php).
13. For more information on school specific guidelines, please consult the LEED® Reference Guide for Green Building Design and Construction.
14. More information on this project can be found in the High Performance Federal Buildings section of the U.S. Department of Energy's Federal Energy Management Program website (http://femp.buildinggreen.com/materials.cfm?ProjectID=805).
15. See http://www.gsa.gov/gsa/cm_attachments/GSA_DOCUMENT/Annual%20Report%20%20FY2004%20Final_R2M- n11_0Z5RDZ-i34K-pR.pdf, accessed July 15, 2010, which states in 2005 that the number of buildings owned by the federal government in the US was 411,406, and the amount of office space within these owned buildings was at that point (September 30, 2004) 2.84 billion square feet.

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