Science Supporting the Economic and Environmental Benefits of Using Wood and Wood Products in Green Building Construction

The use of wood as a building material can provide substantial economic and environmental benefits to our nation's citizens

By Michael A. Ritter, Kenneth Skog, Richard Bergman
USDA Forest Service

Executive Summary

The objective of this report is to summarize the scientific findings that support the environmental and economic benefits of using wood and wood products in green building construction. Wood has been used as a structural material in North America for hundreds of years, primarily for single- and multiple-family housing and transportation structures such as bridges. The market share for wood in commercial buildings, such as schools and strip malls, has been small compared to other materials. Today, a growing awareness of environmental sustainability, and a desire on the part of consumers for quality building materials at economic prices could boost markets for wood products.

Existing use of forest products in the U.S. supports more than 1 million direct jobs and contributes more than $100 billion to the U.S. Gross Domestic Product. Developing wood products from small-diameter trees, dead trees, or brush also returns to land managers much-needed revenue to treat ecosystems devastated by fire, pathogens, or invasive species. Using wood obtained through sustainable forestry practices in green building applications promotes a healthy environment *and* a strong economy.

To take advantage of this win-win opportunity, USDA and other stakeholders must overcome existing misconceptions about wood as a green building material and help lead the research and development efforts on green building materials. Despite documented advantages in many peer-reviewed scientific articles, most building professionals and members of the public do not recognize wood as a renewable resource, or the role efficient wood utilization plays in mitigating climate change and promoting healthy forests. Sustainable forest management can produce stronger, healthier forests that serve as a "carbon sink" to clean air of greenhouse gases and purify drinking water for wildlife and U.S. municipal water systems. Harvested trees can find value in wood products and systems for green building construction that continue to benefit the environment.

A recent lifecycle analysis found that harvesting, transporting, manufacturing, and using wood in lumber and panel products in building yields fewer air emissions–including greenhouse gases–than the resource extraction, manufacture, and use of other common building materials. In fact, wood-based wall systems can require significantly less total energy for manufacturing than thermally comparable houses using other materials. Currently some building codes and standards related to green building do not consider a life cycle environmental analysis that would reveal the environmental advantages of using wood. Greater use of life cycle analysis in building codes

and standards would improve the scientific underpinning of building codes and standards and thereby benefit the environment.

Research and development of wood products and building systems also are lagging that of other materials. A combination of scientific advancement in the areas of life cycle analysis and the development of new technologies for improved and extended wood utilization are needed to continue to advance wood as a green construction material.

USDA will take a lead role in advancing wood as a green building material through the development and implementation of programs that are publicly relevant and appropriate for government. Policy makers as well as the forest products industry and resource management organizations support a science-based approach of outlining the benefits of using wood and wood-based products in green building in the U.S. The inherent benefits of using wood go beyond economic gains. Robust markets for green building materials can enhance the economic incentives for maintaining privately owned forests in forest use--an important consideration given continuing concerns regarding the loss of forestland to development and fragmentation. An "all hands" approach of policy makers, government agencies, industry, academia, and private landowners will be needed to advance scientific knowledge, to bolster development and dissemination of new technologies, and to raise awareness and use of wood in green buildings.

In proclaiming 2011 as the International Year of the Forest, USDA Secretary Tom Vilsack directed the Forest Service to favor wood in new building construction; maintain commitment to certified green building standards; examine ways to enhance research and development projects using green building materials; and, actively work to identify innovative non-residential construction projects that use wood as a green building material. This USDA policy is consistent with President Obama's executive order on Federal Leadership in Environmental, Energy, and Economic Performance.

"Our country has the resources, the work force, and the innovative spirit to reintroduce wood products into all aspects of the next generation of buildings," said Forest Service Chief Tom Tidwell. "As we move forward with restoring America's forests, we are getting smarter and more efficient in how we use wood products as both an energy and green building source. Our progress in this area will also help maintain rural jobs."

Recommendations:

Three inter-related wood industry initiatives will together help further USDA's climate change mitigation and job creation objectives. The latter is particularly noteworthy given the fact that the sector has lost more than one-fourth of its work force over the past five years.
While most people are aware that North American forests help to address climate change by absorbing carbon dioxide from the atmosphere, less well known is the fact that wood products continue to store carbon, thus keeping it out of the atmosphere indefinitely. Substituting wood products for fossil fuel-intensive alternatives also results in significant amounts of "avoided" greenhouse gas (GHG) emissions. To capitalize on wood's carbon benefits, it is proposed that USDA provide information on the following projects:

1. **Research and Development--Life Cycle Assessment**
   A partnership of government, universities and industry is proposed to undertake research needed to support widespread recognition of wood's carbon benefits and ensure its acceptance under emerging green building codes, standards, and rating schemes. Led by the Green Building Strategy Group, a newly established organization composed of industry and non-government organizations (NGOs) to advance green building, this project includes expanding the library of transparent information available to the industry and public, filling critical gaps for wood products in the U.S. Life Cycle Inventory, increasing acceptance and specification of wood as a green building material through the application of complete and current Life Cycle Assessment data and tools, and increasing technical knowledge of and preference for wood products among building science and design/engineering professionals.

2. **Technology Transfer--Wood Use in Non-Residential Buildings**
   The WoodWorks program is a North American program funded by U.S. and Canadian companies, the Forest Service, and some other groups to raise awareness among engineers and architects of the environmental and economic benefits of wood as a green building material. The Woodworks program is nearing the end of its three-year pilot phase and has demonstrated without question that education and technology transfer activities aimed at design and building professionals, including information on wood's carbon benefits, can increase the amount of wood used in non-residential structures. The program is already supporting more than 450 building conversions, which represent an additional 400 million board feet of lumber and 100 million square feet of panels (3/8" basis). Between the carbon stored in the wood products and avoided GHGs, these projects represent a carbon savings of 2.2 million metric tons of CO_2 (equivalent). Supporting WoodWorks as a national initiative over the next five years is expected to increase these wood volumes a total of 5.5 billion board feet and 3 billion square feet respectively, which represents a carbon savings of over 30 billion metric tons of CO_2 (or about 6 million cars off the road for a year). Further, it is expected to significantly contribute to USDA's job creation objectives.

3. **Technology Transfer--Carbon and Green Building Benefits of Typical Wood Structures**
   Working under an established Memorandum of Understanding with the USDA Forest Service, Forest Products Laboratory (FPL), APA-The Engineered Wood Association, will partner with government and forest research organizations to show how carbon storing wood products can be used in typical residential and non-residential construction. The partnership will pursue research and technology transfer activities that demonstrate the advantages of wood over other building materials in green building. This includes activities that build on the success of APA's Florida Carbon Challenge, a program created to educate design and building professionals about the relationships between climate, carbon and everyday building. Design competitions, educational seminars, and the construction of three or four demonstration homes are proposed. This activity will also further the development and use of new or improved wood composites (such as cross laminated timber) to improve the environmental importance of buildings as measured by LCA tools.

By supporting these recommendations, USDA can help to achieve its climate change objectives, while creating jobs, bolstering the competitive position and long-term economic stability of the industry, and reducing U.S. dependence on foreign oil.

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Introduction

USDA is a strong supporter of sustainable forest management on federal, state, and private lands, and manages approximately 20% of U.S. forest land. A key to maintaining healthy forests is to keep management costs reasonable by developing a market for sustainably harvested green products that advance green building. The use of forest products in the United States supports more than a million direct jobs and contributes more than $100 billion to the U.S. Gross Domestic Product. The sustainable use of wood products supports forests, jobs, national income, and a healthy environment. It also contributes to green building by reducing environmental burdens associated with constructing, operating, and decommissioning many other types of buildings.

Benefits of Wood as a Green Building Material

The use of wood as a building material can provide substantial economic and environmental benefits. Economic benefits from producing solid wood products included more than 350,000 direct jobs and $12.0 billion in payroll in 2009. These statistics were down significantly from 460,000 jobs and $15.6 billion in payroll for 2008. Many of these jobs and payroll are especially important in the economic development of rural forested areas. In addition to economic benefits, the development of construction applications for wood from small diameter and bug- or disease-killed trees can support forest conservation management by providing revenue to reduce treatment costs on forest land needing ecological restoration. Increased use of wood for construction also provides revenue to forest land owners that helps incentivize them to keep lands forested and thereby conserve forest ecosystems and a wide range of forest ecosystem services including water purification, water flow regulation, erosion control, stream bank stabilization, carbon sequestration, biodiversity, recreation, and cultural heritage values.

The environmental benefits of using wood over other common construction materials are documented in numerous peer reviewed papers:

- Twenty-two peer reviewed articles in the journal Wood and Fiber Science report the lower environmental emissions associated with U.S. production of 17 wood products used for building construction[1].

[1] Bergman and Bowe 2008; Bergman and Bowe 2010; Hubbard and Bowe 2010; Johnson et al. 2005; Lippke et al. 2010; Kline 2005; Milota et al. 2005; Oneil et al. 2010 ; Oneil and Lippke 2010; Perez-Garcia et al. 2005a; Perez-Garcia 2005b; Puettmann and Wilson 2005a; Puettmann and Wilson 2005b; Puettmann et al. 2010a; Puettmann et

- Two peer reviewed articles in Energy and Buildings report less environmental emissions to construct residential and commercial buildings with wood versus steel and concrete (Gustavsson and Joelsson 2010; Dodoo et al. 2011)
- A paper in Environmental Science and Technology reviewed 21 international studies and found that, on average, each ton of carbon in wood products that is used in place of non-wood products will reduce greenhouse gas emissions by 2.1 tons of carbon (Sathre and O'Connor 2010).
- A paper in the Forest Products Journal (FPJ) indicates how use of wood for all components in a residential wall system--replacing non-wood products--can reduce greenhouse gas (GHG) emissions for product production by as much as two-thirds compared to a conventional wood wall (Lippke et al. 2004). Another peer-reviewed FPJ article shows significant energy reduction and higher material efficiencies over a 30-year time-period for the forest products industry (Meil et al. 2007).

Examples of specific research findings include:

- Fossil fuel consumption, contributions to GHG emissions, and quantities of solid waste tend to be less for manufacturing and use of wood products than for competing products (Werner and Richter 2007).
- Wood products that are installed and used appropriately tend to have lower environmental burdens than functionally equivalent products of other materials (Lipke et al. 2004).
- The analysis of example homes in Minneapolis and Atlanta indicate lower environmental emissions over the life of building materials for homes built with wood than those with steel framing or concrete (Lipke et al. 2004).
- Houses with wood-based wall systems require 15% less total energy for manufacturing than thermally comparable houses using steel- or concrete-based building systems. Over 100 years, net GHG emissions associated with wood-based houses are 20% to 50% lower than emissions associated with thermally comparable houses using steel- or concrete-based building systems (Upton et al. 2008).
- Replacing all non-wood building products in a house with wood alternatives (such as cedar siding, wood windows, and cellulose insulation) could result in net storage of carbon. (Salazar et al. 2009).

Barriers to Increasing Wood Use as a Green Building Material

Wood has been used as a structural material in North America for hundreds of years. Historically, the primary markets for structural wood applications have involved single- and multiple-family housing and transportation structures such as bridges. Although wood has been used with a good performance record in non-residential building applications such as schools,

al. 2010b; Wilson and Sakimoto 2005; Wilson and Dancer 2005a; Wilson and Dancer 2005b; Wilson 2010a; Wilson 2010b; Wilson 2010c; Winistorfer et al. 2005

hotels, strip malls, and offices, the relative market share for wood has been small compared with that of other construction materials. However, a growing emphasis on sustainability and environmental awareness is providing an opportunity for wood to demonstrate attributes that clearly make it a preferred green building material and thus advance the potential to significantly increase the market share for wood products and enhance the vitality of our forests.

Despite clear sustainability advantages, wood is often not considered to be a "green" building material by design professionals and the general public; further, there is confusion about the benefits of renewable (wood) versus recyclable (steel) materials and the true environmental impacts associated with each. Barriers to the full recognition of wood as a green building material include those listed below:

- There is incomplete information on the life cycle environmental impacts of wood and alternative construction materials. Improved life cycle information and simple comparison methods for different materials and building systems are needed to aid building professionals and consumers in the selection of wood as an environmentally preferable construction material.
- Research and development of wood products and building systems is significantly lagging that of other materials. Despite large public sector financing of new technology and product development for other materials, comparative expenditures for wood have been small.
- Most codes and standards related to green building do not include adequate provisions to recognize the benefit of a life cycle environmental analysis to guide selection of building materials. Comparing the true environmental benefits and costs of wood use relative to other materials in green building without life cycle analyses is impossible.
- Insufficient education, technology transfer, and demonstration projects are hindering the acceptance of wood as a green building material. Despite documented advantages, most building professionals and the public in general do not recognize the sustainability of wood and the role efficient wood utilization plays in mitigating climate change and contributing to maintaining the health and vitality of our forests.

Research and Development Can Advance the Use of Wood in Green Buildings

Despite the barriers to increasing wood use as a green building material, the challenges are not overwhelming and positive results can be achieved in a reasonable time period. In response to this opportunity, research and development can play a lead role through a combination of scientific advancement in the areas of life cycle analysis and the development of new technologies for improved and extended wood utilization. Significant contributions can also be made in the areas of codes and standards, education and technology transfer and the development of demonstration projects.

Life Cycle Assessment

Life cycle assessment (LCA) is a well-established set of methods for measuring the environmental impacts of a product or service across its entire life cycle (ISO 2006a, 2006b).

LCA methods are standardized, transparent, credible, and internationally recognized. LCA identifies the flow of materials and energy through the various stages from the point of extracting the raw materials from the environment, through the manufacture, construction, use, and final disposal. The inputs (material and energy) and outputs (emissions) are found for each stage **(Figure 1)**. Using estimates of inputs and outputs, the LCA indicates the burdens the product or service places on the environment over its life cycle.

Specifically, LCAs can identify the emissions to air, water, and land associated with building products and product applications (such as construction). For example, an LCA would estimate the greenhouse gas emissions per cubic foot of product produced, or for construction of a 2,000 square foot house.

LCAs can also be used to improve products or applications by identifying "hot spots" of environmental impacts within a product life cycle. As a result, LCA is increasingly used by businesses to help them identify hot spots and make changes to reach environmental performance goals for products they produce.

Obtaining and organizing life cycle information to allow LCA practitioners to develop LCAs is an ongoing and research intensive task. Life cycle information can be made widely available through the U.S. LCI database maintained by the U.S. Department of Energy's National Renewable Energy Laboratory.

Figure 1. Cradle-to-grave life cycle assessment for wood building products

LCA information is needed to prepare environmental product declarations (EPD) for individual products (ISO 2006c, 2007). An environmental product declaration (EPD) is a summary of the environmental impacts associated with producing and using a product or service **(Figure 2)**. The life cycle information in EPDs can be used to compare the environmental burdens of alternate products. EPDs are meant to communicate standardized LCA information in a way that is meaningful to people who may not be familiar with LCA.

Building architects and engineers can only make choices about environmentally preferable materials if complete life cycle information is readily available for wood and non-wood products and for alternate designs of building components (e.g. walls, floors, roofs).

Research is needed in two broad areas to make life cycle information available:

1) To aid in improving the environmental performance of wood products in buildings there is a need to identify new wood products and building assemblies that have lower life cycle emissions by conducting life cycle assessments for such products and assemblies. In the building industry, individual wood components make up building assemblies while whole buildings are composed of building assemblies. Each of these three--products, assemblies, and whole buildings--require LCAs to determine their environmental performance.

- There is a need to provide software tools for building professionals to evaluate the LCA for a wide range of products and building assemblies for residential and commercial buildings. Developing LCA-based tool for building assemblies and whole buildings is a complex endeavor. LCA-based tools require detailed regionally sourced life cycle information on wood and non-wood products. Providing software tools for building professionals not familiar with LCA would let them design new buildings and redesign older buildings with less environmental impacts. The ATHENA EcoCalculator is one software tool that can analyze a limited number of building assemblies. There is a need for tools that can analyze more assemblies and whole structures and can analyze designs for specific geographic areas that take into account regional factors such as hot humid weather, earthquakes and flooding.

2) To make life cycle information available to consumers and general public as well as architects and builders, there is a need to develop additional product LCAs specifically to prepare EPDs for all wood construction materials. EPD information can be condensed into a table similar to nutritional labels on food products (Figure 2). The U.S. trails Europe and parts of Asia in developing EPDS.

Impact category	Unit	Per 1 m^2 of siding	Per 100 ft^2 of siding
Total primary energy:	MJ	280.08	2601.96
Non-renewable, fossil	MJ	138.84	1289.80
Non-renewable, nuclear	MJ	8.28	76.89
Renewable (SWHG)	MJ	17.00	157.97
Renewable, biomass	MJ	4.50	41.81
Feedstock, non-renewable fossil	MJ	6.46	60.00
Feedstock, renewable biomass	MJ	105.00	975.49
Renewable material consumption (wood)	kg	4.65	43.24
Non-renewable material consumption (nails, paint)	kg	0.37	3.42
Fresh water use	L	1.01	9.40
Total waste	kg	5.02	46.66
Hazardous	kg	0.00	0.00
Non-hazardous	kg	5.02	46.66
Global warming potential (GWP)	kg CO_2eq	4.64	43.11
Acidification potential	H+ moles eq	4.15	38.59
Eutrophication potential	kg N eq	6.71E-03	6.23E-02
Smog potential	kg NO_x eq	6.17E-02	5.73E-01
Ozone depletion potential	kg CFC-11 eq	3.20E-07	2.97E-06

SWHG: Solar, wind, hydroelectric and geothermal
Note: GWP includes all biogenic carbon sinks and sources throughout the product system boundary.

Figure 2. Life cycle information provided by EPD for western red cedar siding

- Basic life cycle information previously compiled for some wood products needs to be updated to meet EPD requirements. In order to make the best product comparisons, life cycle information needs to be updated every 3 to 5 years to account for technology changes and new regulations.

- To assure there is transparent and peer reviewed data for EPDs, there is a need to provide up-to-date life cycle information to the U.S. LCI Database. The U.S. LCI Database (www.nrel.gov/lci) is a library of life cycle data for many products including building products. Life cycle information has been uploaded for over 15 region-specific wood products to date. The data was provided by research conducted by the Consortium for Research on Renewable Industrial Materials (CORRIM) funded in part by the FPL. CORRIM is a non-profit research consortium of 15 universities that has partnerships with the FPL and the ATHENA Institute.

- In addition to basic life cycle information for the processes to produce a product, an EPD requires life cycle information on product use in specific applications such as buildings

and disposal of products from these buildings. Obtaining life cycle information for applications and disposal is a research intensive activity requiring a large amount of data and analysis.

New Technology

Research can advance the use of wood in green buildings through development of new product technologies. An example of a new technology in the U.S. for wood-based building systems is cross laminated timber (CLT), which allows for large, solid-wood structural panels to be factory manufactured from low-value, small-diameter, and insect- and disease-killed trees. Suitable for multi-story buildings that substantially exceed current height limitations on conventional wood-frame construction, it is a good material for non-residential green building construction. Although previously used in Europe, CLT is a new product in the United States, and research is needed to establish economic and resource parameters for market development and structural performance criteria required for building code acceptance.

Nanotechnology is another new technology that has the potential to significantly advance wood as a green building material. Nanotechnology is the understanding and control of matter at dimensions approximately 1 to 100 nanometers, where unique phenomena enable novel applications. A sheet of paper is about 100,000 nanometers thick and a gold atom is about one-third of a nanometer in diameter. Unusual physical, chemical, and biological properties can emerge in materials at the nanoscale. These properties differ in important ways from the properties of bulk materials and single atoms. Nanotechnology holds great promise to revolutionize materials used in the 21st century, while wood-based nanomaterials provide the key materials platform for the sustainable production of renewable, recyclable, and environmentally preferable goods and products to meet the needs of people in our modern society. Our ability to see materials down to nanoscale dimensions and to determine and alter how materials are constructed at the nanoscale provides an opportunity to develop new materials and products in previously unimagined ways. Nanotechnology will result in novel forms of wood-based construction materials and products that have superior performance and serviceability under the most severe end use environments. Use of nano-dimensional cellulose in nanocomposites also will allow the production of much lighter weight materials to replace metals and plastics in many applications.

Codes and Standards

The provisions of building and material codes and standards are critical for the widespread acceptance of wood as a green building material. The use of scientifically consensus-based green building certification standards can also help the USDA meet climate mitigation strategic objectives nationwide. The USDA 2010-2015 Strategic Plan, Strategic Goal No. 2, is intended to ensure that our national forests and private working lands are conserved, restored, and made more resilient to climate change, while enhancing our water resources. Objective 2.2 is intended to lead efforts to mitigate and adapt to climate change. The mitigation role of forests under Objective 2.2 includes identifying and supporting the appropriate role that wood products can play in building construction that mitigates GHC emissions and other environmental burdens. Green building certification standards that identify and credit use of materials that mitigate GHG emissions as well as other environmental burdens can support achievement of Objective 2.2.

There are two key privately developed green building standards[2] for commercial buildings:

1. LEED by the U.S. Green Building Council (USGBC).
2. Green Globes, an outgrowth of BREEAM (defined?) from the Canadian Standards Association that operates in the United Sates under the auspices of the Green Building Initiative (GBI). On March 24, 2010, the GBI Green Building Assessment Protocol for Commercial Buildings was approved as the nation's first and only American National Standard Commercial Building Rating System by the American National Standards Institute (ANSI/GBI 01-2010).

There are three green building consensus-based standards:

1. The National Green Building Standard (NGBS), ICC 700-2008, developed by the National Association of Home Builders and the International Code Council under the ANSI standards process is for new construction and remodeling for all residential building types including single-family, multi-family, and residential portions of mixed-use buildings. The scope of the NGBS rating standard is inclusive of land development, lots, and buildings. It is the only ANSI-accredited standard for residential construction.
2. The ASHRAE 189.1 Standard for the Design of High-Performance Green Buildings developed with USGBC and the Illuminating Engineering Society (IES), released on January 22, 2010, is a code intended as a commercial green building standard.
3. International Green Construction Code (IGCC), now in development through the International Code Council (ICC), is intended for incorporation in 2012 international codes.

CALGREEN is the first statewide green building code law. The California state legislature approved measures to adopt LEED as code for commercial and residential construction but was vetoed by Governor (Brown? Schwarzenegger?), affirming that the state should have a role in developing and adopting standards. The State Standard Commission was directed to develop a statewide green code. The code became mandatory on January 1, 2011. Currently many elements are voluntary, but it is anticipated by state leaders that many will become required over time.

In January 2010, New York City leaders announced that they will develop a green building code for the city based on the IGCC. Additionally, the city of Phoenix, Arizona is developing a green building code that is scheduled to be implemented in July, 2011.

As a research organization, USDA Forest Service Research and Development supports the use of life cycle assessment science to guide development of green building certification standards. All of the standards referenced above, except LEED, incorporate LCA in one way or another within existing standards. LCA is currently recognized only as a pilot credit within LEED. Proposed

[2] Information for this section is from "Potential game changers in green building: new developments signal a fundamental shift and perhaps significant opportunities for building materials suppliers" by Bowyer et al 2010. http://www.dovetailinc.org/files/DovetailGrnBldg0410.pdf

standards vary in the degree to which they use LCA science in determining which system designs and materials would cause the lowest environmental burdens.

The existing national scope of green building certification standards differs to a limited degree in how and to what degree wood use is considered "green." These standards are:

- The National Green Building Standard, ICC 700-2008, is an ANSI-approved standard that allows wood to contribute in the resource efficiency section with use of certified wood products, engineered wood, locally sourced wood, recycled-content materials, and salvaged materials. Credit is also given if LCA tools are used in building design and in the selection of materials.
- ASHRAE/USGBC/IES 2009 requires that 60% of all wood used in construction be chain-of-custody certified (with the certification program to meet standards of ISO/IEC Guide 59, or the WTO Technical Barriers to Trade document). Support is given for use of recycled-content materials, salvage and reuse, and locally sourced materials. There is a requirement that LCA be performed for a minimum of two alternative building designs.
- IGCC draft standard is comprehensive and includes language supporting the use of certified wood and LCA in building design and the selection of construction materials.
- LEED currently provides credits only for use of Forest Stewardship Council certified wood and locally sourced wood. LEED is piloting an approach to incorporate LCA into all its standards. Were the pilot to be adopted as currently written, structural/envelope assemblies would be evaluated with an LCA impact calculator and up to 7 credits would potentially be awarded based on the magnitude of impact of the selected assemblies versus the average and lowest impact options.

The latest green building initiatives indicate a clear trend toward requiring green in building construction that includes demand for recycled-content, re-used/refurbished products, regionally sourced materials, and certified wood. In addition, with language regarding LCA now in all of the new national scope standards, as well as the new California code and the Green Globes standard, and perhaps fully integrated into the USGBC LEED program in the future, there is every indication that use of LCA represents a new way of doing business in green building evaluation.

LEED is the most widely used green building standard for new non-residential buildings. An estimated 2.4 billion square feet of low-rise residential buildings (4 stories or less) were constructed in 2009. This is based on estimated expenditures from the U.S. Department of Commerce and the estimated square feet per dollar of expenditures from McGraw-Hill Corporation. Based on some analyses, as much as 25 percent of all non-residential building starts are registered with LEED. However, a recent estimate indicates that only one-half of the registered building starts follow through with full certification.[3] Using these fractions and wood use rates per square foot of low rise buildings, an estimated 294 million square feet was certified

[3] From "Green building market and impact report 2009" by R. Watson, GreenerBuildings.com. http://www.greenbiz.com/sites/default/files/GreenBuildlingImpactReport2009.pdf

and the associated wood use was approximately 390 million board feet. However, these figures should be considered order of magnitude estimates and require further confirmation. Wood is also used in other residential and commercial buildings that are green certified by LEED or other standards so the total wood use will be larger. However, even if the amount is off by a factor of 2 or more, it is likely to be only a small fraction of the estimated 57 billion board feet of lumber consumed in the United States in 2009.

Steps that the USDA could take in the area of codes and standards to expand the use of wood in green building include:

1. Support standards that use LCA to choose building designs and materials that reduce environmental burdens.
2. Endorse Forest Service adoption of the American Society for Testing and Materials Standard D7612-10, Standard Practice for Categorizing Wood and Wood-Based Products According to Their Fiber Sources.
3. Support research that provides necessary data for the U.S. Life Cycle Inventory Database.

Education and Technology Transfer

While most people are aware that North American forests help to address climate change by absorbing carbon dioxide from the atmosphere, less well known is the fact that wood products continue to store carbon, thus keeping it out of the atmosphere indefinitely. Substituting wood products for fossil fuel-intensive alternatives also results in significant amounts of "avoided" greenhouse gas emissions.

Technology transfer and education are key components of research that can significantly influence the preference for wood as a green building material. USDA Forest Service Research & Development is a partner in the U.S. WoodWorks program, which is nearing the end of its three-year pilot phase. This program has clearly demonstrated that education and technology transfer activities aimed at design and building professionals, including information on wood's carbon benefits, can increase the amount of wood used in non-residential structures. The program already supports more than 450 building conversions to wood from other materials, representing 400 million board feet of lumber and 100 million square feet of panels (3/8-inch basis). Between the carbon stored in the wood products and avoided GHGs, these projects represent a carbon savings of 2.2 million metric tons of CO_2 (equivalent). Supporting WoodWorks with continued funding and technical expertise over the next five years is expected to increase these wood volumes by 5.5 billion board feet and 3 billion square feet, which represents a carbon savings of over 30 million metric tons of CO_2 (equivalent to removing approximately 6 million cars off the road for a year).

Demonstration Projects: The Forest Service is currently involved in four demonstration projects in three locations: two structures at the Forest Products Laboratory in Madison, Wisconsin; one on the campus of Mississippi State University; and one under construction on the campus of Haywood Community College in Canton, North Carolina. These demonstration structures provide educational outreach on wood as a sustainable building material and afford an

opportunity to conduct "real world" research specific to a geographic region. The structures are each unique, but all demonstrate wood as a green building material and emphasize the influence of regional climatic parameters on durability, energy efficiency, and livability.

A demonstration-related project recently promoted by the Forest Service and the wood products industry was the Florida Residential Carbon Challenge, a competition for architects to design a house with the lowest carbon footprint. The objectives of this competition were to increase understanding and development of single-family house designs that meet the structural and thermal requirements of the 2007 Florida Building Code and to move toward reduced carbon footprint and fossil fuel use in Florida (and the broader U.S. South). The visibility of a state-wide competition was aimed at encouraging building professionals and developers to incorporate such designs into their homes and communities. Although the competition did not specifically require the use of wood as a primary construction material, all 36 of the submissions involved wood-frame designs. The winning design was awarded to True Design Studios of Jacksonville, Fla., at the 2011 National Association of Home Builders International Builders Show in Orlando. As a follow-up to the competition, APA--The Engineered Wood Association is sponsoring 10 seminars to educate architects and engineers on the sustainability aspects of wood-frame housing.

Although green building and sustainability are typically associated with buildings, the same principles can be applied to the transportation infrastructure. The Forest Service has partnered with Iowa State University to construct several demonstration bridges in Iowa. In these cases, sustainability considerations and availability of local wood species have demonstrated that wood is an excellent material for bridge replacement for the rural transportation infrastructure.

There are several potential cooperative demonstration projects that will further demonstrate the use of wood as a green building material including:

- Six research/demonstration houses located in Washington, California, Arizona, Florida, Georgia, and North Dakota
- A partnership to construct the Forest Service National Museum using CLT
- Numerous CLT demonstration structures with the Forest Service National Forest System
- Construction of 10 demonstration wood highway bridges in the Midwest and South

Concluding Remarks and Recommendations

The USDA has the opportunity to take a lead role in advancing wood as a green building material through the development and implementation of programs that are publically relevant and are an appropriate role for government. Policy makers as well as the forest products industry and resource management organizations support a science-based approach of outlining the benefits of using wood and wood-based products in green buildings in the United States. An interdisciplinary approach is needed to further develop scientific knowledge and provide technology transfer and education relevant to evaluating and advancing these benefits. It must be noted that the inherent benefits of using wood go beyond economic gains. Sound forest management leads to increased forest productivity, cleaner water, and enhanced wildlife habitat. Part of maximizing the environmental benefits of wood as a building material is to fully understand the benefits of sustainable forestry practices on the overall environmental

impact. This includes assessing the impact of outreach and education, conservation cost share, and certification programs on the footprint of wood building materials. From this it will be possible to identify techniques for maximizing benefits and transfer these practices through partner networks of state forestry agencies, extension services, and sustainable forestry organizations.

The following annual programs are proposed to advance wood use in green building:

Life Cycle Assessment (LCA)
A partnership of government, universities, and industry is proposed to undertake research needed to support widespread recognition of wood's carbon benefits and ensure its acceptance under emerging green building codes, standards, and rating schemes. Led by the Green Building Strategy Group, a newly established organization composed of industry and non-government organizations, or NGO's, to advance green building, this project includes expanding the library of transparent information available to industry and the public, filling critical gaps for wood products in the U.S. Life Cycle Inventory, increasing acceptance and specification of wood as a green building material through the application of complete and current LCA data and tools, development of EPDs, and increasing technical knowledge of and preference for wood products among building science and design/engineering professionals. For maximum impact, the group will also ensure that all key stakeholders understand the science behind LCAs and EPDs and appropriately promote their use. Workshops to engage key stakeholders, share research findings, solicit input and further environmental understanding will extend outreach to materials scientists, public agencies, the conservation community and policymakers.

Wood Use in Non-Residential Buildings
The U.S. WoodWorks program, which is nearing the end of its three-year pilot phase, has demonstrated that education and technology transfer activities aimed at design and building professionals, including information on wood's carbon benefits, can increase the amount of wood used in non-residential structures.

Carbon and Green Building Benefits of Typical Wood Structures
A partnership is proposed between government and forest research organizations to show how carbon storing wood products can be used in typical residential and non-residential construction. The partnership will pursue research and technology transfer activities that demonstrate the advantages of wood over other building materials in green building. This effort includes activities that build on the success of the Florida Carbon Challenge, a program designed to educate design and building professionals about the relationships between climate, carbon, and everyday building. In additiona to design competitions, educational seminars and the construction of three or four demonstration homes are proposed. This effort will also further the development and use of new or improved wood products and technologies (such as cross laminated timber) to extend utilization of the forest resource and improve the environmental importance of buildings as measured by LCA tools.

By supporting these initiatives, the USDA can help to achieve its climate change objectives, while creating jobs, bolstering the competitive position and long-term economic stability of the industry, and reducing U.S. dependence on foreign oil.

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