Cathedral of Christ The Light
Oakland, California
Design architect:
Skidmore, Owings & Merrill

Photo by Timothy Hursley

Rethinking Wood as a Material of Choice

Costs less, delivers more

Sponsored by reThink Wood | *By Layne Evans*

Designers today are finding new possibilities in one of the oldest building materials on earth. Wood has always been valued for its beauty, abundance and practicality, but many of wood's inherent characteristics are rising to very current challenges. Wood's traditional values and newest technologies meet in the projects presented in this course, illustrating the advantages of wood in four areas: cost-effectiveness in a wide range of projects; adaptability for use in challenging, visionary new designs; lower environmental costs throughout its life cycle, from its source in renewable, carefully managed forests, through an energy-efficient service life, and often on to a new, recycled and reimagined use; and a unique human-nature connection that has always been intuitive, but is now being documented in research.

COST CONSCIOUS

As a material grown throughout North America, wood can be locally sourced and is usually less expensive than alternative building materials. Wood building systems also typically cost less to install when construction is viewed as a whole, for a number of reasons. Wood is readily available and tends to be delivered quickly, and most communities have a large pool of qualified tradespeople with wood framing experience,

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Learning Objectives

After reading this article, you should be able to:

1. Compare the material, project and environmental costs of wood to other building materials.
2. Explain innovative wood technologies and how they are contributing to a wide range of sustainable designs.
3. Discuss the environmental impact of wood throughout its life cycle, including its renewability, certification options, impacts on energy efficiency, low carbon footprint, and end-of-life recycling and reuse.
4. Examine research and examples demonstrating the positive impact of exposed wood on a building's occupants.

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Photo by Matt Todd, courtesy of WoodWorks

Environmental recognition with local green building programs was a plus for the Marselle Condominiums in Seattle, Washington, designed by PB Architects, but cost was the driving factor in the decision to use wood construction.

which minimizes construction delays and keeps labor costs competitive. Wood's adaptability and ease of use also translate into faster construction schedules, while a smaller foundation may be needed because of its light weight.

For the Carroll Smith Elementary School in Osceola, Arkansas, wood's light weight indirectly led to savings. The project was originally designed in concrete block. This would have required expensive piers to address soft soil conditions. The project team also looked at using steel construction elements, which were found to concentrate the load in unacceptably small areas. Ultimately, the project team selected wood thus reducing both the need for piers and the cost of the structural system. According to Ferran Espin of PKM Architects, lead designer for the project, using wood for the walls, floor and roof deck saved approximately $10 per square foot compared to a steel structure with light metal gauge framing. John Warriner of John Warriner and Associates, also part of the architectural team, said wood was the natural choice for this project given its economic value and design flexibility. Designing the building using wood allowed the team to meet all of the project requirements in the most financially responsible way.

In addition to material costs, an aggressive construction schedule was one of the main drivers for the choice of wood in Emory Point, a mixed-use project near Emory University in Atlanta, Georgia. Designed by Cooper Carry and The Preston Partnership, the 442-unit project includes one five-story wood-frame building over slab-on-grade and three four-story wood-frame buildings over one-story concrete podiums. According to Brad Ellinwood, PE, of Ellinwood + Machado Consulting Structural Engineers, a number of systems were considered but wood was by far the most economical. For the structural frame portion only, the wood design cost approximately $14/square foot compared to $22/square foot for a 7-inch post-tensioned concrete slab and frame. Despite the need for significant site preparation, wood's ease of use allowed the entire project to be completed in just over a year.

Often, even when wood is chosen to meet other goals, cost is still the deciding factor. For the Marselle Condominium project in Seattle, Washington, wood construction helped the building meet requirements of the local Master Builders Association Built Green program. But while the environmental recognition was an added benefit, the developer considered the decision to use wood framing purely financial. "If the project had been built using all concrete, for instance, it would have cost about 30 percent more," according to Kory Knudson, vice president of Norcon, NW, Inc. "If we had built the entire project out of steel, it would have taken much longer and we would have had to make many energy modifications."

INNOVATIVE USES FOR A TRADITIONAL BUILDING MATERIAL

Building codes recognize wood's structural performance capabilities in a broad range of applications—from the light-duty repetitive framing common in small structures to the larger and heavier framing systems used to build arenas, schools and other large buildings. However, around the world, architects and structural engineers are extending the boundaries of wood design, while innovative technologies and building systems continue to expand opportunities for wood use in construction. It's a symbiotic relationship that has also influenced the evolution of building codes and standards.

For example, the Cathedral of Christ The Light in Oakland, California, is an extraordinary timber cathedral designed to last 300 years using a unique structural system. Designed by Skidmore, Owings & Merrill LLP (SOM), the soaring 36,000-square-foot, 1,500-seat structure replaces another cathedral destroyed during a 1989 earthquake. Architecturally stunning, the new building features a space-frame structure comprised of a glulam and steel-rod skeleton veiled with a glass skin. Given the close proximity of fault lines and non-conformance of the design to a standard *California Building Code* lateral system, the City of Oakland hired a peer review committee to review SOM's design for toughness and ductility. Through the use of advanced seismic engineering, including base isolation, the structure has been designed to withstand a 1,000-year earthquake. Engineers were able to achieve the appropriate structural strength and toughness by carefully defining ductility requirements for the structure, using three-dimensional computer models that simulate the entire structure's nonlinear behavior, testing of critical components relied on for seismic base isolation and superstructure ductility, and verifying their installation.

An example with farther-reaching implications is the Long Hall in Whitefish, Montana, the first commercial building in the U.S. to be built from cross laminated timber (CLT). Although the Type VB structure was built to 2009 *International Building Code* (IBC) requirements, CLT was completely new to code officials. Darryl Byle, PE, of CLT Solutions worked with the local building department more than six months in advance to address concerns and keep the project on schedule. Among the challenges, the team needed approval of the CLT system as a stand-alone, one-hour rated assembly in order to feature exposed CLT on the interior. Byle used data on fire design from sources such as the *National Design Specification® (NDS®) for Wood Construction* and experimental CLT fire test data from manufacturers and independent sources to demonstrate that CLT panels could be expected to perform well in a fire event.

In addition to CLT, parallel strand lumber (PSL), glued laminated timber (glulam) and prefabricated paneling systems are among the products contributing to a wider range of wood buildings. They have made wood a viable choice for applications such as arenas, gymnasiums and lobbies, which require tall walls and large open spaces with minimal, intermediate supports.

Photo by gravityshots.com

Speed record: Taking speed of construction to an entirely new level, the two-story Long Hall in Whitefish, Montana, designed by Datum Design Drafting and engineered by CLT Solutions, took just five days to erect and gave the owner a sustainable, energy-efficient building. It was the first commercial building in the U.S. made from CLT.

For example, glulam can be manufactured to achieve spans as long as 100 feet and walls up to 20 feet. (See the case study of the Art Gallery of Ontario renovation designed by Frank Gehry, page 7.)

Photo by Sean Weaver

Galleria Italia at the Art Gallery of Ontario. (See case study on page 7.)

WOOD AND THE ENVIRONMENT

Wood grows naturally and is renewable. Life cycle assessment (LCA) studies also show that wood yields clear environmental advantages over other common building materials in terms of embodied energy, air and water pollution, and greenhouse gas emissions.

In the past, the green building movement has taken a prescriptive approach to choosing building materials. This approach assumes that certain prescribed practices—such as using local materials or specifying products with recycled content—are better for the environment regardless of the product's manufacturing process or disposal. Today, however, it is being replaced by the scientific evaluation of actual impacts through LCA.

LCA is an internationally recognized method for measuring the environmental impacts of materials, assemblies or whole buildings over their entire lives—from extraction or harvest of raw materials through manufacturing, transportation, installation, use, maintenance and disposal or recycling. When integrated into green building codes, standards and rating systems, LCA encourages design professionals to compare different building designs based on their environmental impacts and make informed choices about the materials they use.

A comprehensive review of scientific literature[1] looked at research done in Europe, North America and Australia pertaining to life cycle assessment of wood products. It applied LCA criteria in accordance with ISO 14040-42 and concluded, among other things, that:

- Fossil fuel consumption, the potential contributions to the greenhouse effect and the quantities of solid waste tend to be minor for wood products compared to competing products.
- Wood products that have been installed and are used in an appropriate way tend to have a favorable environmental profile compared to functionally equivalent products made from other materials.

It's worth taking a closer look at some of the important aspects that contribute to this favorable environmental profile.

Sustainable Source

Sustainable forest management involves meeting society's need for forest products and other benefits, while respecting the values people attach to forests and preserving forest health and diversity for the future. In North America, responsible forest management ensures that forests are legally harvested and managed to meet society's long-term demand for forest products and other sustainability goals. In the U.S. and Canada, this has resulted in more than 50 consecutive years of net forest growth that exceeds annual forest harvests.[2] The rate of deforestation in the U.S. and Canada is virtually zero.[3]

Wood is also the only building material that has third-party certification programs in place to demonstrate that products being sold have come from a sustainably managed resource.

THE TREND TOWARD TALLER WOOD BUILDINGS

Multi-family housing was one of the first market segments to rebound from the recession, because it's more affordable than single-family housing while offering advantages such as less upkeep and closer proximity to amenities. Wood construction is attractive for multi-family projects because it offers high density at a relatively low cost, as well as adaptability on site, faster construction, and reduced carbon footprint. The IBC allows wood-frame construction for five stories and more (e.g., with the use of mezzanines and terraces) in building occupancies that range from business and mercantile to multi-family, military, senior, student and affordable housing. However, there are indications that this may increase as new products continue to enhance wood's ability to add value in multi-story applications. For example, cross laminated timber (CLT) is widely used in Europe and is gaining ground in North America. In Australia, a ten-story CLT building was completed in 2013, and there are eight- and nine-story examples in the UK and Austria.

LCA IN CODES, STANDARDS AND RATING SYSTEMS

LCA is more common in Europe than North America, but its use is increasing in both markets because of its holistic approach and power as an evaluative tool. For example:

The UK-based Building Research Establishment's Environmental Assessment Method (BREEAM) is the world's most widely used green building rating system and the basis for many others, including the Leadership in Energy and Environmental Design (LEED) system and Green Globes. The BREEAM modules for offices, multi-family buildings and ecoHomes include calculations based on LCA.

In the U.S., LCA is encouraged in the Green Globes rating system, and included in the American National Standard based on Green Globes, *ANSI/GBI 01-2010: Green Building Assessment Protocol for Commercial Buildings*. With the release of LEED v.4, a pilot credit related to LCA has been replaced with optional credits related to LCA, LCA-based environmental product declarations (EPDs), material ingredient verification and raw material extraction.

LCA is incorporated in the draft *California Green Building Standards Code*, American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) *Standard 189.1, National Green Building Standard* (ICC 700), and *International Green Construction Code* (IGCC).

Sustainable forest certification allows forest companies to demonstrate the effectiveness of their practices by having them independently assessed against a stringent standard that considers environmental, economic and social values. As of August 2013, approximately 500 million acres of forest in the U.S. and Canada were certified under one of the four internationally recognized programs used in North America: the Sustainable Forestry Initiative (SFI), Forest Stewardship Council (FSC), Canadian Standards Association's Sustainable Forest Management Standard (CSA), and American Tree Farm System (ATFS). This represents more than half of the world's certified forests.

Carbon Footprint

As trees grow, they absorb carbon dioxide from the atmosphere. They release the oxygen and incorporate the carbon into their wood, roots, leaves or needles, and surrounding soil. One of three things then happens:

- As trees mature and then die, they start to decay and slowly release the stored carbon back into the atmosphere.
- The forest succumbs to wildfire, insects or disease and releases the stored carbon quickly.
- The trees are harvested and manufactured into forest products, which continue to store much of the carbon. In the case of wood buildings, the carbon is kept out of the atmosphere for the lifetime of the structure—or longer if the wood is reclaimed and manufactured into other products. Wood stores more carbon than is emitted during its harvest, production, transport and installation.

In all of these cases, the cycle begins again as the forest regenerates and trees once again begin absorbing and storing carbon.

Putting these benefits into perspective, one carbon calculator[4] (see box on the next page) found that the Avalon Anaheim Stadium, a five-story building constructed of wood (Withee Malcolm Architects, engineering by VanDorpe Chou Associates Inc.) in Anaheim, California, stored 3,970 metric tons of carbon dioxide equivalent (CO_2e) in its lumber and sheathing, while the emissions avoided by not using steel or concrete increased the carbon benefit by another 8,440 metric tons of CO_2e. According to the U.S. Environmental Protection Agency's Greenhouse Gas Equivalencies Calculator, this equates to the annual emissions from 2,370 cars or the energy to operate an average home for 1,050 years.

Energy Efficiency

In terms of operating energy, wood has the advantage of low thermal conductivity compared to steel and concrete. As a result, wood is easy to insulate to high standards while steel and concrete must overcome problems from thermal bridging and the possible consequence of moisture condensation on cold surfaces. However, because there are many factors that have a greater influence on a building's energy efficiency (such as insulation and air tightness), the more relevant point for many designers is that wood building systems lend themselves to structures that are highly energy efficient—with less impact on the environment in terms of embodied energy, air and water pollution, and carbon footprint.

Any wood structural system can be designed to achieve a tight building envelope. However, with new systems such as CLT, precise manufacturing results in tight tolerances and exceptional air tightness. The added aspect of dimensional stability also ensures that the building remains airtight over time. Wood is also proving to be a good choice for designers who want to meet the Passive House (Passivhaus) standard or create a net-zero energy or net-zero carbon building.

Recycle/Reuse

One of the most important sustainability factors for a building material is often underestimated or overlooked completely: what will happen to the material at the end of the building's working life? A "Survey on Actual Service Lives of North American Buildings" showed that

Photo by Arden Photography, courtesy of VanDorpe Chou Associates

According to the U.S. EPA Greenhouse Gas Equivalencies Calculator, estimated carbon benefits for the five-story Avalon Anaheim Stadium equate to a year's worth of emissions from 2,370 cars or the energy to operate an average home for 1,050 years.

CARBON CALCULATOR

A carbon calculator available free to design professionals estimates the carbon benefits of wood buildings. Users input the volume of wood products, and the calculator estimates the amount of carbon stored in the wood and the greenhouse gas emissions avoided by using wood. If volume information isn't known, users may select from typical building types.
Source: www.woodworks.org

buildings in the U.S. often have a service life of less than 50 years, regardless of material, because of changing needs or increasing land values as opposed to performance issues. When one considers the embodied energy in these structures and issues related to disposal, the adaptability of wood structures and building systems, either through renovation or deconstruction and reuse, is a significant advantage. (See "Adaptive Reuse" case study on the Federal Center South – Building 1202 on page 7.)

BRINGING NATURE TO THE INTERIOR ENVIRONMENT

As buildings become increasingly dependent on and designed for technology, the human need to connect with nature doesn't change, but it can get harder to accommodate. Wood has unique characteristics that most people respond to intuitively. This positive connection is being documented by a growing body of research, and can be a valuable asset in spaces filled with electronic devices and screens, synthetic materials and artificial lighting.

People feel an instinctive connection and attraction to natural materials, and many building designers cite the warm attributes of wood as a reason for its use. Evidence also suggests that exposed wood can contribute to an individual's sense of well-being. In an office or school, wood is thought to improve performance and productivity; in a hospital, it may have a positive impact on patient recovery.

A study[5] at the University of British Columbia and FPInnovations found that the presence of visual wood surfaces in a room lowered activation of the sympathetic nervous system (SNS). The SNS is responsible for physiological stress responses in humans such as increased blood pressure and heart rate while inhibiting the parasympathetic system responsible for digestion, recovery and repair functions in the body. The study immersed 119 university students in one of four different office environments, some with wood surfaces and others without. Stress as measured by SNS activation was lower in the wood rooms in all periods of the study. The study concluded that wood is one way to create a healthier built environment.

Study author David Fell says that research on wood and schools is underway, but the results of the office study apply to any interior environment. "The stress-reducing effects we found for wood in office environments are in theory transferable to any building type as these are innate reactions to natural materials.

Another example is the Herrington Recovery Center in Oconomowoc, Wisconsin, a 21,000-square-foot, 20-bed treatment center for executives and business professionals. Cedar and stained wood were used inside and out. Wood ceilings and soffits in the recreation room and entrances to sleeping rooms brought warmth to the space, while exposed glulam beams allowed for soaring ceilings and clerestory windows provided ample natural light. Patient rooms had shorter spans, so the dividing walls between patient rooms were designed as bearing walls. This allowed the use of cost-effective 2x lumber for ceiling joists. "Certainly from a cost standpoint, it made a lot of sense to do the whole thing on a wood frame," said architect John Curran, ALA, senior vice president for TWP Architecture. "And by using wood in what some might consider an institutional setting, we were able to create a warm and familiar environment to make patients feel more comfortable and more at home."

Designed by Salter Farrow Pilon Architects, the Thunder Bay Regional Health Sciences Center in Ontario was the first hospital in Canada to gain approval for the use of wood as a

Photo by www.naturallywood.com

Thunder Bay Regional Health Sciences Center in Ontario, designed by Salter Farrow Pilon Architects Inc., was the first hospital in Canada to gain approval for the use of wood as a primary structural element.

primary structural element. Featuring a dramatic three-story wood and glass walkway, the structure incorporates over 1,100 glulam members, some more than 65 feet long. The use of wood extensively throughout the structure provides a bright and optimistic atmosphere for patients, staff, and the community.

CONCLUSION

With growing pressure to reduce the carbon footprint of the built environment, building designers are increasingly being called upon to balance functionality and cost objectives with reduced environmental impact. Wood can typically help to achieve that balance.

Wood costs less—economically and environmentally—while delivering more in terms of its beauty, versatility and performance. It meets code requirements in a wide range of low- and mid-rise building types, and innovative new technologies continue to expand the possibilities for wood use in construction. Wood can also deliver a deep connection to nature that will only become more valuable in our built environment as humans continue to advance, and to stay the same.

ENDNOTES

1) Werner, F. and Richter, K. 2007. *Wooden building products in comparative LCA: A literature review*. International Journal of Life Cycle Assessment, 12(7): 470-479

2) Calculated by Dovetail Partners Inc. based on data from Natural Resources Canada and the USDA Forest Service.

3) *Deforestation in Canada - What are the Facts*, Natural Resources Canada; *State of the World's Forests*, 2011, United Nations Food and Agriculture Organization

4) U.S. WoodWorks Carbon Calculator, www.woodworks.org

5) www.solutionsforwood.com/_docs/reports/Wood_Human_Health_final-single.pdf

CASE STUDIES

COST-EFFECTIVE GREEN SCHOOLS

Bethel School District (BSD) is proving that building green doesn't have to cost a lot. While the District reports an 81 percent ENERGY STAR rating overall, several of their 17 elementary and six junior high schools have a rating ranging from 95 to 98 percent. While size, configuration and age of the 23 facilities varies, one thing remains constant: each is wood-frame.

Wood-frame schools can be easily designed to meet and exceed the demanding energy efficiency requirements of environmentally-minded school districts. And, they can do so cost effectively. One of BSD's new elementary schools, completed in 2011, had a total construction cost of $197.70 per square foot—a significant savings compared to the average construction cost of an elementary school in western Washington, which is $250.07.

BSD credits several factors in their success. In western Washington, wood studs cost almost half as much as metal; $0.53 per lineal foot for wood versus $0.98 for metal studs. Also, wood studs don't transfer heat and cold the way metal studs do, so wood helps improve the energy efficiency of the exterior envelope. Finally, wood-frame walls, floors and roofs easily accommodate inexpensive batt insulation, making it simple and cost-effective to over-insulate.

Of their 23 schools and one learning center, 18 have earned the ENERGY STAR label, and BSD has received national recognition from the U.S. Environmental Protection Agency as an ENERGY STAR Leader.

Photo by Bethel School District

Spanaway Junior High School, Bethel School District, Spanaway, Washington

ADAPTIVE REUSE

Federal Center South – Building 1202, Seattle, Washington
Architect: ZGF Architects LLP
Completed: 2012
WoodWorks Award Winner: Commercial Wood Design

Photo by Benjamin Benschneider

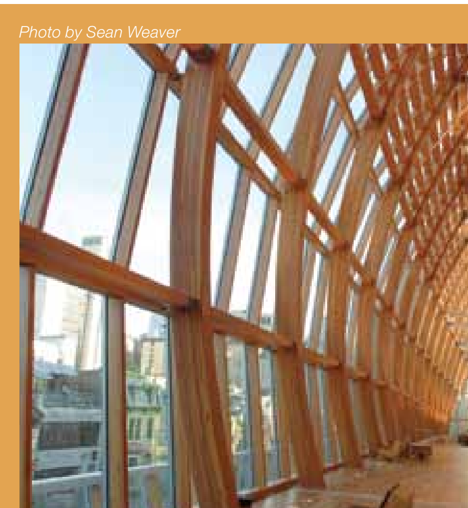
Seattle District headquarters for the U.S. Army Corps of Engineers is a LEED Gold-certified project partially funded through the U.S. GSA's Design Excellence Program, established to procure the nation's best engineers and architects in order to achieve the most innovative and high-performance design in federal government buildings. All of the wood used in the project was salvaged from a 1940s-era warehouse that previously occupied the site—a total of 200,000 board feet of heavy timber and 100,000 board feet of 2x6 tongue and groove roof decking. The heavy timber is featured fully exposed in the central commons, which includes conference rooms, libraries, restrooms and gathering areas. However, because the amount of reclaimed wood was limited, composite timber-concrete beams were also used to increase beam spacing and allow the entire program to be met with wood from the warehouse. Heavy timber was also used on the walking surfaces of interior pedestrian bridges and stairs, incorporated into the exterior entry canopy, and milled for use as hand railings and ceiling finishes, while reclaimed decking was also used for interior wall paneling.

GALLERY RENOVATION

Art Gallery of Ontario
Toronto, Ontario (Canada)
Architect: Frank Gehry
Completed: 2008

After the renovation of the existing gallery and addition of 92,000 square feet of new floor space, the Art Gallery of Ontario (AGO) has been called "the most complex wood structure in North America." The Dundas Street facade includes 1,800 glulam members, each of which is unique, as are the 2,500 glulam connectors. The designers developed three-dimensional solid models and wireframe models for each glulam application, complete with calculated loads and member sizing. A wireframe of the models was sent to the subcontractor responsible for the connection engineering, detail drafting, manufacturing, delivery, and installation of the glulam. This information was used to develop a working solid model that included the glulam members, connections and hardware. The model was used to create shop drawings for approval and eventually for data input to the CNC equipment used to machine each glulam member to exacting tolerances and to shape the complex framing for each connector. In addition to the impressive structural applications, wood was used decoratively to provide visual highlights throughout the interior.

Photo by Sean Weaver



COST-EFFECTIVE LUXURY

Stella
Marina del Rey, California
Architect: DesignArc
Completed: 2013

At this luxury mixed-use development, the design team mixed cost-effective wood framing with a sleek, contemporary exterior.

Two things make this project unique: the fact that it includes a Type III building with five stories of wood and a Type V building with four stories of wood on a shared concrete podium, and the use of prefabrication to speed the building process.

The wood-frame portion of the development consists of Douglas-fir dimension lumber along with parallel strand lumber (PSL), laminated strand lumber (LVL), glulam beams and engineered wood I-joists for the floor and roof structures. The project uses both plywood and oriented strand board (OSB) structural wood sheathing.

One of the keys to Stella's success was coordination. With limited room on site, the developer, GLJ Partners, hired the framer to begin working on the wall panels about eight months prior to construction, which GLJ estimates "saved a few hundred thousand dollars just in general conditions and supervision."

Adding to the savings, the framer says panelization typically takes 10 to 15 percent off the timeline compared to traditional site-built construction. If there hadn't been delays with the podium, he says the Stella could have been entirely framed in 20 weeks, which is fast for a building of its size and level of complexity.


Photo by Lawrence Anderson, www.lawrenceanderson.net

Construction cost for the project, which includes 244 apartment units, retail space, parking, and amenities such as a heated saltwater pool, sand beach and fitness center, was $65 million.

THE ENVIRONMENT

There are many remarkable examples of wood buildings that have been designed to blend with their environment, and give occupants a deep connection to nature inside and out. Two shown here closely combine the traditional values of wood with new techniques for sustainable building.

David and Lucile Packard Foundation
Los Altos, California
Architect: EHDD
Completed: 2012
WoodWorks Award Winner: Green Building with Wood

Photo by Jeremy Bittermann; courtesy of EHDD

Wood was used extensively in this 49,000-square-foot LEED Platinum, net zero energy company headquarters, emphasizing the building as a healthy and sustainable place to work. By combining exposed wood inside with views to the outdoor courtyard, the architect created a relaxed environment where the occupant is in constant contact with nature.

James and Anne Robinson Nature Center
Columbia, Maryland
Architect: GWWO, Inc./Architects
Completed: 2011
WoodWorks Award Winner: Institutional Wood Design

Photo by Robert Creamer Photography and Paul Burk Photography

Given the 26,000-square-foot Robinson Nature Center's role of connecting visitors with nature, it was important that the structure appear modest on approach and in keeping with its setting, while minimizing impacts on the site. Achieving LEED Platinum certification was of paramount importance to the client as its mission is to educate the public about environmental stewardship. By specifying wood that was either FSC-certified, low-emitting, recycled and/or regionally produced, seven LEED points were gained, helping this goal to be met.