

# Windows and Sustainability: An Environmental Perspective

## Windows and doors can contribute to green design and LEED® credits

May 2007 – By Barbara A. Nadel, FAIA

Former Vice President Al Gore has used the success of *An Inconvenient Truth*, which won an Academy Award for best documentary film, to educate the public about global warming, climate change, and the need for energy-efficient public policies. As a result, a design issue that has long been of great concern to architects and the building industry has captured the imagination and attention of the media, public officials, business communities, and global citizens of every generation who wish to inhabit a healthier planet.

“Buildings and their construction account for nearly half of all the greenhouse gas emissions and energy consumed in the U.S. annually. This includes energy used in the production and transportation of materials to construction sites, and energy used to operate buildings. Looked at another way, America’s buildings emit as much carbon as the entire economies of Japan, France, and Great Britain combined. Architects who understand and apply sustainability principles contribute to increased energy efficiency and building occupant performance, while lowering energy costs and the environmental burden of buildings on the environment,” says R.K. Stewart, FAIA, principal of Gensler, San Francisco, and 2007 AIA National President.

According to Edward Mazria, AIA, founder of Architecture 2030 ([www.architecture2030.org](http://www.architecture2030.org)), U.S. annual energy consumption is projected to increase by 37 percent and greenhouse gas emissions by 36 percent over the next 20 years. Global energy consumption is expected to increase by 54 percent over this same period. Promoting sustainable design practices will curb emissions and reduce global warming. Resource conservation can contribute to achieving a minimum of 50 percent reduction from the current level of consumption of fossil fuels used to construct and operate buildings by the year 2010.

This article will explore how the Leadership in Energy and Environmental Design (LEED®) Green Building Rating System guides architects through a process that promotes sustainable best practices. Opportunities for obtaining LEED credits with windows, using LEED-NC, Version 2.2, will be discussed, along with a comparison of the sustainable qualities of wood, aluminum, and vinyl window frames.

### U.S. Green Building Council

The U.S. Green Building Council (USGBC) is a national nonprofit organization that was formed in 1993, with a membership of building industry groups and individuals. The committee-based organization has developed industry standards, design practices, policy advocacy, information exchange, and education tools. USGBC developed and runs the LEED Green Building Rating System.

The goal of sustainable design is to create high-performance buildings. This concept evolved from various concerns and needs within society and the building industry. Green design is a term referring to design and construction practices that significantly reduce or eliminate the negative impact of buildings on the environment and occupants in five areas:

- Sustainable site planning
- Safeguarding water and water efficiency
- Energy efficiency and renewable energy
- Conservation of materials and resources
- Indoor environmental quality

According to the U.S. Department of Energy (DOE), in 2001, buildings consumed two-thirds of U.S. electricity use, one-eighth of water consumption, and transform land that provides valuable ecological services. In 1998, the U.S. Environmental Protection Agency (EPA) found that over 136 million tons of construction and demolition waste were generated in the U.S., at approximately 2.8 lbs/person/day.

Green building provides many benefits to societies that improve the quality of life, from environmental, economic, health, and safety, to community perspectives. The net effect is to:

- Reduce impacts of natural resource consumption
  - Protect air and water quality, biodiversity, and ecosystem health
  - Improve economics of building operations, asset value, worker productivity, and the local economy
  - Enhance building occupant health and safety, relating to risk management
  - Minimize strain on local infrastructure, such as landfills, water supply, storm water sewers and related development and costs; decrease transportation development and maintenance for roadways, and encourage better performance of mass transit systems.
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At the Lakeside Nature Center in Kansas City, aluminum-clad wood fixed windows with low-E glass provide a beautifully framed connection to the outdoors while allowing maximum daylight with minimum heat gain. Courtesy of Pella Corporation

LEED is a national benchmark for high-performance green buildings. It promotes sustainable design and construction, and facilitates positive results for the environment, occupant health, and financial return. LEED provides a green standard of measurement that can prevent green washing, or false, exaggerated claims, and advances integrated design processes. This rating system is a design guideline that identifies industry leadership, stimulates green competition, raises consumer awareness, and has transformed the marketplace with sustainability concepts.

LEED offers building owners and operator's tools to have an immediate and measurable impact on building performance and implement a whole-building approach to sustainability, through the aforementioned five areas of human and environmental health. LEED provides a method to document success for every building type and life cycle phase, through several programs including LEED-NC for New Commercial Construction and major renovation projects.

## LEED-NC

Since inception, LEED programs have been updated periodically with new releases. LEED-NC 2.0 was released in 2000. As of January 1, 2006, all new projects must be registered under Version 2.2. Windows and doors can contribute to one prerequisite and up to 25 points.

Designers should verify the latest applicable versions and their criteria. The LEED rating system is on a five-year review cycle with the development of LEED-NC Version 3.0, in progress.

The whole-building approach encourages and guides a collaborative, integrated design and construction process. LEED is performance-based where possible, compatible with standard design processes, self-evaluating, self-documenting, but not self-certifying. Certification is done solely by USGBC. There are four levels of LEED-NC certification, using a point system: Certified level (26-32 points); Silver (33-38 points); Gold (39-51 points), and Platinum (52-69 points).

The LEED rating system certifies buildings, not building materials. However, building materials can contribute to achieving LEED points, only a few of which are dependent upon third party certification or proving equivalence to a given standard.

LEED-NC point distribution is spread throughout five credit categories: Sustainable Sites: 22 percent; Water Efficiency: eight percent; Energy and Atmosphere: 27 percent; Materials and Resources: 20 percent; and Indoor Environmental Quality: 23 percent.

These five environmental categories are divided into credits. For each credit, the rating system identifies the intent, requirements, and technologies or strategies to obtain the credit. One or more points are available within each credit, and points are achieved by meeting the requirements. Most categories contain prerequisites. All seven prerequisites must be met in order to qualify for any certification level. In addition to the five environmental categories, there is also an Innovation and Design Process category, for a total of six categories, seven prerequisites, and 69 possible points.

Achieving LEED Points	Possible Points	Points related to windows & doors
1. Sustainable Sites	14	1
2. Water Efficiency	5	0
3. Energy and Atmosphere	17	13
4. Materials and Resources	13	5
5. Indoor Environmental Quality	15	5
6. Innovation and Design Process	5	1
<b>Total</b>	<b>69</b>	<b>25</b>

**Sustainable Sites**

Windows and doors can contribute to one point in the Sustainable Sites category.

Light Pollution Reduction, Credit 8 seeks to minimize light trespass from the building and site, reduce sky-glow to increase night sky access, improve nighttime visibility through glare reduction, and reduce development impact on nocturnal environments. Although most of this credit addresses outdoor lighting, it mentions light trespass from interior lighting that shines out through windows at night. The proper use of window treatments, to reduce glare, or direct lighting onto neighboring property, streets or night sky, can contribute to this credit.

**Water Efficiency**

The second major category, Water Efficiency, has no contributions from windows and doors.

**Energy and Atmosphere**

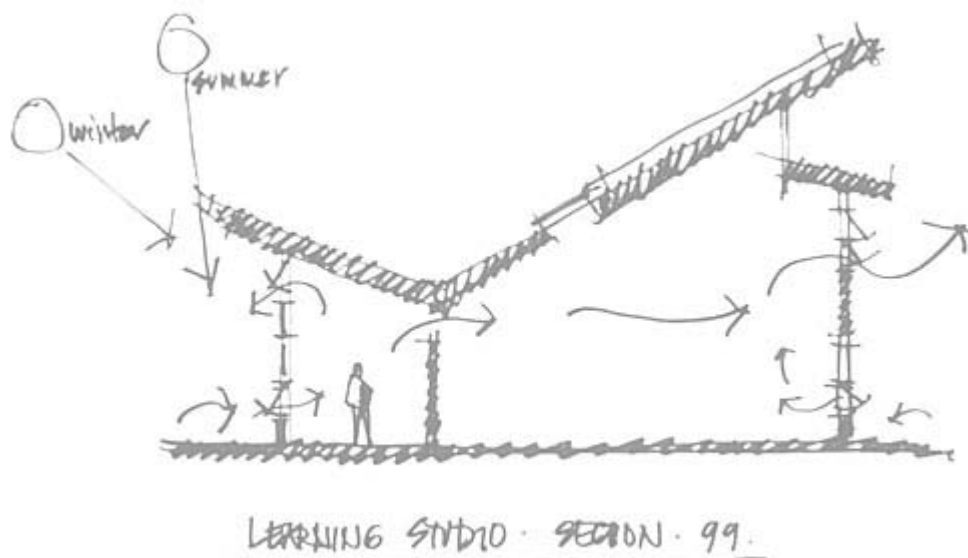
In the third category, Energy and Atmosphere (EA), windows and doors can contribute to one prerequisite and up to 13 points.

Minimum Energy Performance, Prerequisite 2 calls for establishing the minimum level of energy efficiency for proposed buildings and systems. Building projects should be designed to comply with both the mandatory provisions (Sections 5.4, 6.4, 7.4, 8.4, 9.4, and 10.4) of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)/IESNA Standard 90.1-2004 (without amendments), and the prescriptive requirements (Sections 5.5, 6.5, 7.5, and 9.5) or performance requirements (Section 11) of ASHRAE/IESNA Standard 90.1-2004 (without amendments).

Potential strategies include designing the building envelope, HVAC, lighting, and other systems to maximize energy performance. The ASHRAE 90.1-2004 User's Manual contains worksheets that can document compliance with this prerequisite. For projects pursuing points under EA Optimize Energy Performance, Credit 1, computer simulation modeling may be used for confirmation of this prerequisite.

If a local code has demonstrated quantitative equivalence following, at minimum, the DOE standard process for commercial energy code determination, then it may be used to satisfy this prerequisite instead of ASHRAE 90.1-2004. For details on the DOE process for commercial energy code determination, see [www.energycodes.gov/implement/determinations\\_com.stm](http://www.energycodes.gov/implement/determinations_com.stm).

Optimize Energy Performance, Credit 1 addresses increasing levels of energy performance above the baseline in the prerequisite standard to reduce environmental and economic impacts associated with excessive energy use. The number of points increases as energy costs decline. Project teams can select one of three compliance path options. Documenting achievement using any of the three options is assumed to be in compliance with EA Minimize Energy Performance, Prerequisite 2. The options are: Option 1: Whole Building Energy Simulation (1-10 points), Option 2: Prescriptive Compliance Path for small office buildings (four points), and Option 3: Prescriptive Compliance Path (one point).



Strategically-located windows enable natural ventilation and reduce reliance on energy-dependent mechanical systems.

Drawing credit: Mithun Architects + Designers + Planners, Seattle, WA

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Many window strategies can be used to help achieve Credit 1, including:

- Minimize undesirable air infiltration. Window weather-stripping at the sash to frame juncture and backer rod and sealant/foam at the window to opening intersection reduce air infiltration.
- Locate windows and shading devices to maximize day lighting and minimize heat gain.
- Use high performance glazing to optimize natural day lighting, heating, and cooling. Low emissivity glass reduces heat gain while allowing visible light. Triple glazing offers center glass U-values as low as 0.16.
- Avoid thermal bridging from metal framing by specifying fiberglass, vinyl, or wood frames or aluminum frames with high performance thermal breaks.
- Locate windows to employ natural ventilation and reduce reliance on energy-dependent mechanical systems.
- Specify between-the-glass blinds since they perform better than room side blinds. With the blinds closed, between-the-glass blinds offer an 18-percent improvement in total window U-value and a 43 percent reduction in solar heat gain when compared to room side blinds.

On-site Renewable Energy, Credit 2, encourages and recognizes increasing levels of on-site renewable energy self-supply, to reduce environmental and economic impacts associated with fossil fuel energy use. Use of on-site renewable energy systems will offset building energy cost. Project performance can be calculated by expressing the energy produced by the renewable systems as a percentage of the building annual energy cost. Points can be achieved based on the percentage of renewable energy used: 2.5 percent achieves one point, 7.5 percent achieves two points, and 12.5 percent achieves three points.

Projects can be assessed for non-polluting and renewable energy potential, including the use of photovoltaic's in building elements such as the roof, exterior cladding, or window systems.



With the blinds closed, between-the-glass blinds offer an 18-percent improvement in total window U-value and a 43-percent reduction in solar heat gain when compared to room side blinds.

Wayland Union Middle School, Wayland, MI Design Plus, Inc.

#### Materials and Resources

Windows can contribute to five points in the fourth major category, Materials and Resources (MR).

Recycled Content, Credit 4, calls for an increased demand for building products that incorporate recycled content materials, thereby reducing impacts resulting from extraction and processing of virgin materials. Credit 4.1, worth one point, addresses use of materials with recycled content such that the sum of post-consumer recycled content plus one-half of the pre-consumer content constitutes at least 10 percent (based on cost) of the total value of project materials. Credit 4.2, worth one point, goes a step further, with an additional 10 percent beyond MR Credit 4.1 (total of 20 percent, based on cost), of the total value of project materials.

Post-consumer material is waste generated by households, commercial, industrial, and institutional facilities, in their role as product end-users, and can no longer be used for its intended purpose.

Pre-consumer material is material diverted from the waste stream during the manufacturing process. Excluded is reutilization of materials such as rework, regrind or scrap generated in a process and capable of being reclaimed within the same process that generated it. Windows that include recycled materials like aluminum, glass, and wood can help with this credit.

Regional Materials, Credit 5, addresses an increased demand for building materials and products that are extracted and manufactured within the region, thereby supporting the use of indigenous resources and reducing the environmental impacts resulting from transportation. Credit 5.1, worth one point, discusses the use of building materials or products that have been extracted, harvested, or recovered, and manufactured within 500 miles of the project site for a minimum of 10 percent (based on cost) of the total materials value. Credit 5.2, worth one point, expands this idea, with an additional 10 percent beyond MR Credit 5.1 (total of 20 percent, based on cost) of the total materials value.

If only a fraction of the material is extracted, harvested, recovered, and manufactured locally, then only that percentage by weight shall contribute to the regional value. Project goals can be established for locally sourced materials and suppliers, to ensure that specified local materials are installed during construction. Environmental, economic, and performance attributes should be reviewed when selecting products.

**Rapidly Renewable Materials, Credit 6, addresses reduced use and depletion of finite raw materials and long-cycle renewable materials by replacing them with rapidly renewable materials. Credit 6, worth one point, discusses the use of rapidly renewable building materials and products (made from plants typically harvested within a ten-year cycle or shorter) for two-and-a-half percent of the total value of all building materials and products used on a project.**

Since the primary materials used in windows (aluminum, glass, wood, and vinyl) come from sources where the time from origination to harvest exceeds 10 years, windows cannot help on this credit. If the harvest time were increased, many pine wood windows would be applicable. Under Version 2.2, pine does not qualify for LEED certification as a rapidly renewable material. Pine has a 20-year growth and harvest cycle, and is a plentiful, sustainable material.

Certified Wood, Credit 7, encourages environmentally responsible forest management. Credit 7, worth one point, addresses the minimum use of 50 percent of wood-based materials and products, certified in accordance with the Forest Stewardship Council's (FSC) Principles and Criteria, for wood building components including, but not limited to, structural framing, flooring, finishes, furnishings, and non-rented temporary construction applications. Since most wood windows use very little FSC-certified wood, the window contribution to this credit is small. Non-certified wood windows may be used, and the credit can still be earned, through FSC-certified wood in millwork, interior doors, flooring, and other applications.

#### Indoor Environmental Quality

Windows can contribute to five points in the fifth major category, Indoor Environmental Quality (IEQ). Americans spend an average of 90 percent of their time indoors, where pollutant levels may be up to 100 times higher than outdoor levels, according to the EPA.



At IslandWood, a LEED® Gold project in Bainbridge Island, WA, Mithun specified operable wood windows to achieve optimum thermal comfort without air conditioning and with minimal need for heating.

Images: IslandWood (PSELC), Bainbridge Island, WA Mithun

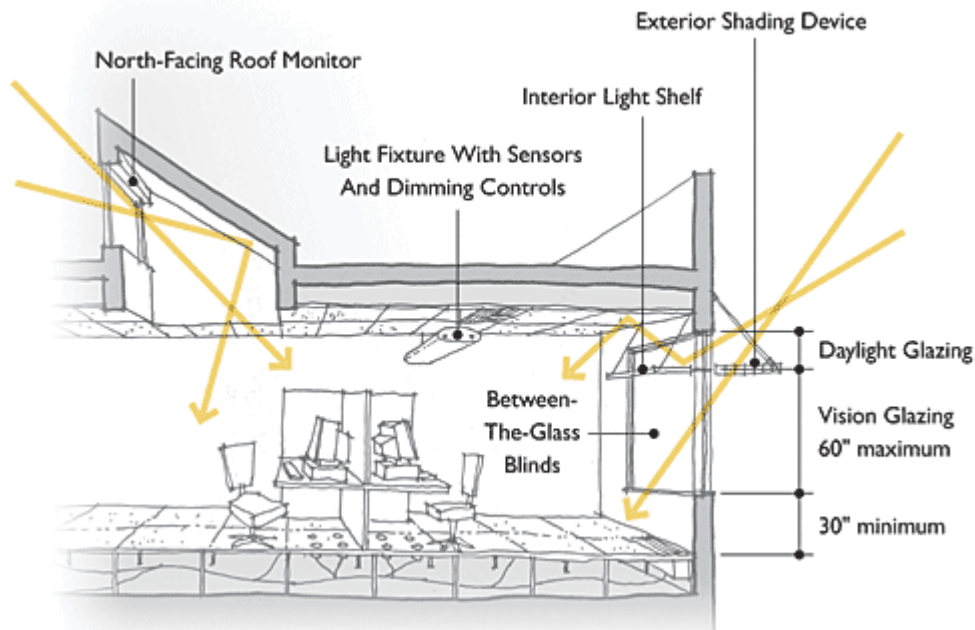
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Increased Ventilation, Credit 2, discusses providing additional outdoor air ventilation to improve indoor air quality for enhanced occupant comfort, well-being, and productivity. Credit 2, worth one point, has two parts. Mechanically ventilated spaces should increase breathing zone outdoor air ventilation rates to all occupied spaces by at least 30 percent above the minimum rates required by ASHRAE Standard 62.1-2004 as determined by IEQ Prerequisite 1, Minimum Indoor Air Quality (IAQ) Performance. Naturally ventilated spaces should design natural ventilation systems for occupied spaces to meet recommendations in the Carbon Trust “Good Practice Guide 237,” 1998. Operable windows to naturally ventilate spaces can contribute to this credit.

IslandWood, a LEED Gold-certified project in Bainbridge Island, Washington, designed by Mithun Architects, is an environmental learning center. This project meets the LEED 1.0 energy credit, which requires no active heating or cooling for eight months of the year. Windows and doors contributed to 12 of the 40 points that helped this project achieve LEED Gold. The windows did not contain FSC-certified wood, but the project earned credit for FSC wood elsewhere. Operable windows enabled natural ventilation.

Low-Emitting Materials, Paints and Coatings, Credit 4.2, aims to reduce the quantity of indoor air contaminants that are odorous, irritating, and harmful to the comfort and well being of installers and occupants. Credit 4.2, worth one point, offers criteria for paints and coatings on building interiors (inside the weatherproofing system and applied on-site). Architectural paints, coatings, and primers applied to interior walls and ceilings should not exceed the volatile organic compounds (VOC) content limits established in Green Seal Standard GS-11, Paints, First Edition, 1993. Clear wood finishes, floor coatings, stains, and shellacs applied to interior elements should not exceed the VOC content limits established in South Coast Air Quality Management District, Rule 1113, 2004. Architects can ensure that VOC limits are stated in the paints and coating specifications.

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Many design strategies can be used to maximize day lighting while reducing glare.

Illustration source: LEED-NC Reference Guide. © 2005 U.S. Green Building Council. Used with permission. To learn more about green building and LEED®, visit [www.usgbc.org](http://www.usgbc.org)

Controllability of Systems: Thermal Comfort, Credit 6.2, calls for a high level of thermal comfort system control by individual occupants or by groups in multi-occupant spaces, such as classrooms and conference areas, to promote the productivity, comfort, and well-being of building occupants. Credit 6.2, worth one point, addresses individual comfort levels for 50 percent minimum of the building occupants, to enable adjustments to suit individual needs. Operable windows can be used in lieu of comfort controls for occupants of areas that are 20 feet inside of, and 10 feet to either side of the operable part of the window. The areas of operable windows must meet the requirements of ASHRAE 62.1-2004, on natural ventilation. Comfort system controls for shared spaces should allow adjustments for individual and group needs.

Design strategies to achieve these goals may include the use of operable windows, mechanical systems, or a combination of both. Individual adjustments may involve thermostat controls, diffusers at floor, desk or overhead levels, and radiant panel controls.



Daylight Zone (Clear Low-E)

Vision Zone (Gray Low-E)



Hoffman Corporation, an architectural firm in Appleton, WI, incorporated a variety of sustainable strategies in the design of their corporate office.

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Daylight and Views: Daylight 75 Percent of Spaces, Credit 8.1, encourages providing building occupants a connection between indoor spaces and the outdoors through the introduction of

daylight and views into the regularly occupied areas of the building. Credit 8.1, worth one point, has three options (calculation, simulation, or measurement), all requiring performance in a minimum of 75 percent of all regularly occupied areas.

Courtyards, atriums, clerestory windows, skylights, interior light shelves, exterior fins, louvers, and adjustable blinds used alone, or in combination, are effective strategies to achieve deep daylight penetration. The desired amount of daylight will differ depending on the tasks occurring in a day lit space. Day lit buildings often have several daylight zones with differing target light levels. In addition to light levels, day lighting strategies should address interior color schemes, direct beam penetration, and integration with the electric lighting system.

Glare control is perhaps the most common failure in day lighting strategies. Glare is defined as any excessively bright source of light within the visual field that creates discomfort or loss in visibility. Large window areas provide generous amounts of daylight to task areas. If not controlled properly, this daylight can produce unwanted glare. Measures to control glare include light shelves, louvers, blinds, fins, and shades.

Hoffman Corporation, an architectural firm in Appleton, WI, incorporated several of these strategies in the design of their corporate offices, including:

- Exterior and interior light shelves between the daylight zone and the vision zone
- Clear low-E glass above the light shelf for maximum visible light transmission
- Gray low-E glass below the light shelf to control glare
- White ceilings reflect light deep into the space
- Between-the-glass blinds in the east and west-facing windows block unwanted heat gain
- Triple glazing with multiple low-E coatings reduce heat loss on the north side of the building.

Daylight and Views: Views for 90 Percent of Spaces, Credit 8.2, calls for providing building occupants with a connection between indoor spaces and the outdoors, through the introduction of daylight and views into the regularly occupied areas of the building. Credit 8.2, worth one point, requires achieving direct line of sight to the outdoors through vision glazing between two feet six inches and seven feet six inches above finished floor for building occupants in 90 percent of all regularly occupied areas. The area with direct line of sight can be determined by totaling the regularly occupied square footage. In plain view, the area should be within sight lines drawn from perimeter vision glazing. In section view, a direct sight line can be drawn from the area to perimeter vision glazing.

Spaces can be designed to maximize day lighting and view opportunities. Strategies include lower partition heights, interior shading devices, interior glazing, and automatic photocell-based controls.

“Building form and orientation can be designed to capture more daylight opportunities. Floor plans should maximize perimeter daylight zones. A standard window can produce useful illumination to a depth of about one and one-half times the window height. The higher the

window is placed on the wall, the deeper the daylight penetration,” says Susan K. Oldroyd, AIA, LEED-AP, associate, RossDrulisCusenbery Architecture, Sonoma, CA.



Daylight and views are required for at least 75 percent of all regularly occupied areas in order to achieve IEQ Credit 8.1.

### **Innovation and Design Process**

Windows may contribute to points in this last major category. New technologies are continually introduced into the marketplace, as scientific research influences building design. This category recognizes projects for innovative building features.

Innovation in Design, Credit 1, describes how design teams can be awarded points for exceptional performance above LEED requirements and innovative performance in categories not addressed in the LEED Green Building Rating System. Credits 1.1 to 1.4, each worth one point for up to four independent measures, can identify proposed compliance requirements, submittals demonstrating compliance, and innovative design approaches to meet the requirements.

Windows can contribute to achieving this credit. Strategies that greatly exceed LEED requirements might include those with energy-

efficient measures with extraordinary savings. Points for exemplary performance are available only when outcomes produce outstanding, measurable benefits.

Innovation strategies not addressed by existing LEED credits must demonstrate significant environmental and occupant benefits. For example, a visitors center showing substantial effort, such as an interactive display, web site, and video, would show a level of effort meriting an innovation credit.

LEED Accredited Professional, Credit 2 encourages design integration required for a LEED project to streamline the application and certification process. Credit 2, worth one point, requires at least one principal participant of the project team who successfully completed the LEED Accredited Professional (LEED-AP) exam. Windows do not typically help with this credit, but the accredited professional can integrate design, credits, and identify appropriate strategies.

### **Environmental Impacts of Window Frame Materials**

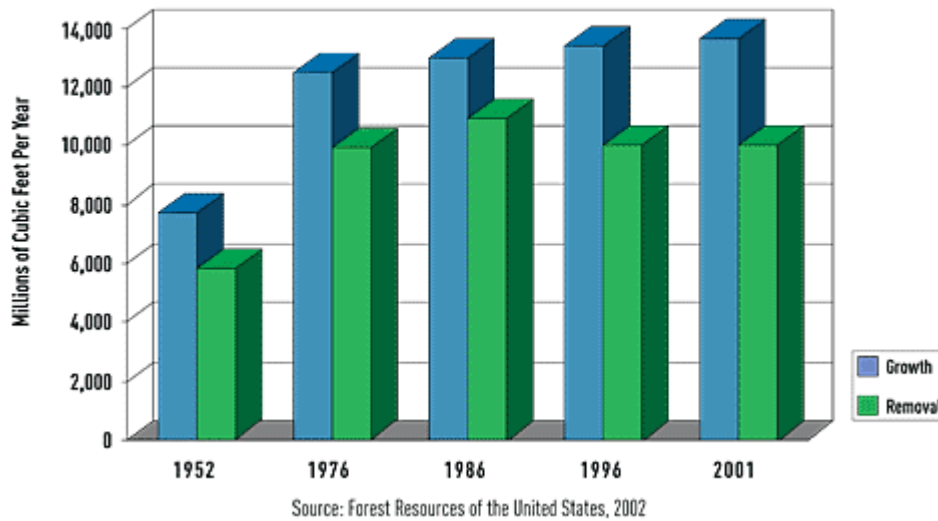
Understanding the life cycle of building products is important for meeting sustainability goals. The following life cycle comparison of three common types of window framing materials, aluminum, vinyl, and wood, is based on eight evaluation categories: source material, renewable, recycled content, embodied energy, pollution produced, energy consumed, recyclable, and

biodegradable. There is not yet much third-party research available on fiberglass windows, so this material cannot be fully addressed.

**Primary Source of Raw Materials:** Aluminum is made from bauxite. It is an abundant natural mineral with an approximate 300-year supply but is sourced primarily from locations outside the United States. Plastic or vinyl windows are made from fossil fuels, which, according to some sources, may have only a 50-year supply remaining. Wood comes from trees, which, if planting rates remain at current rates, will continue to increase in supply.

**Renewable:** Of the three window frame materials, aluminum, vinyl, and wood, only wood is derived from a rapidly renewable resource. According to the Forest Resources of the U.S (2002), the net volume of softwood on U.S. forestlands was 12 percent greater in 1997 than in 1953. When forests are properly managed, wood is a sustainable resource. The net volume of wood in U.S. forests is increasing, as a result of sustainable forest techniques. In 2001, the volume of softwood growth exceeded the volume of softwood removal by 36 percent.

## National Softwood Growth & Harvest



The net volume of wood in U.S. forests is increasing, as a result of sustainable forest techniques. In 2001, the volume of softwood growth exceeded the volume of softwood removal by 36 percent.

**Recycled Content:** Recycled content is commonly included in windows made from aluminum and wood. Both extruded and roll-formed aluminum can contain recycled content without degrading the end product. Recycled wood is commonly used in wood window frames. Short wood pieces that are too small for sash parts are often finger jointed together to form lengths that can be used in wood window frames. The building industry continues to debate the amount of recycled content used in vinyl window production. According to an industry master specification

system, most lineal extruders of vinyl use 100 percent virgin polyvinyl chloride (PVC) resins and do not recommend PVC resins containing recycled content.

Embodied energy refers to the amount of energy required to manufacture and supply a product, material, or source to the point of use. It includes all of the energy used to create one pound of a finished product, from raw material extraction, to transport, manufacturing, assembly, and building installation. Wood and recycled aluminum require the least amount of production energy.

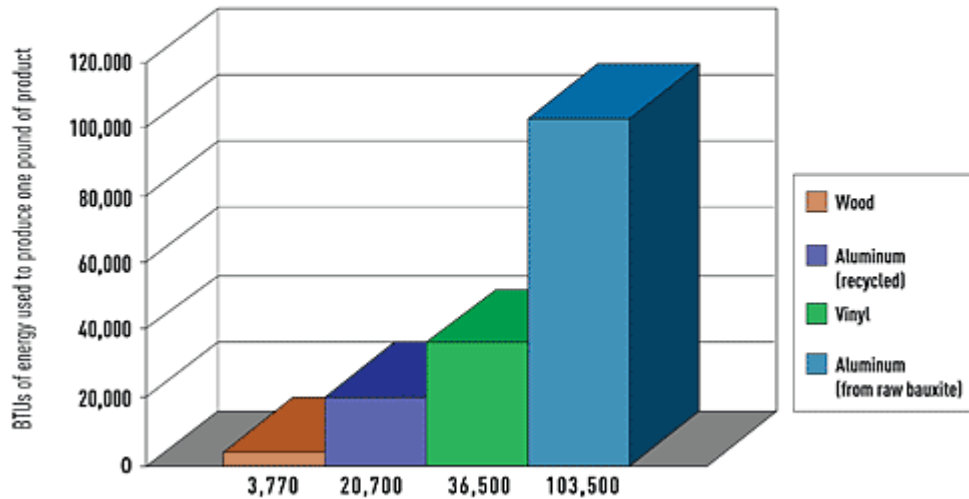
According to AIA's Environmental Resource Guide, wood requires 3,770 British thermal units (BTU) per pound (BTU/lb); recycled aluminum needs 20,700 BTU/lb, vinyl consumes 36,500 BTU/lb, and aluminum uses 103,500 BTU/lb from raw bauxite. Approximately 27.5 percent of total aluminum production comes from recycled aluminum.

In a study from the UK, "Life Cycle Analysis of Window Materials - A Comparative Analysis," (Napier University School of Engineering, Edinburgh, 2002) an embodied energy analysis of standard windows concluded that aluminum windows used the most embodied energy, while PVC required about three times as much embodied energy as wood. The study stated that aluminum and wood windows typically last over 40 years, while PVC has an optimum life of 25 years.

Pollution Produced During Manufacturing: Energy use results in pollution. Assuming the same type of energy is used to manufacture aluminum, vinyl, and wood window frames, varying amounts of pollution are typically generated. According to a 1993 preliminary air and water emissions study by the Western Woods Products Association, wood windows produced far less pollution than aluminum. Air emissions from aluminum were eight times higher than for wood. Water emissions from aluminum were 300 times higher than for wood. Carbon dioxide (CO<sub>2</sub>) emissions from aluminum were 26 times higher than for wood, and from vinyl were 11 times higher than for wood.

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# Embodied Energy



Source: AIA Environmental Resource Guide

Wood windows and doors require the least amount of embodied energy in their production.

The aforementioned UK study, “Life Cycle Analysis of Window Materials,” concluded that aluminum window frames cause the highest environmental impact because of dangerous pollutants released and high energy consumption during production. PVC contributes large amounts of poisonous pollutants throughout its life cycle, while wood window frames have the fewest environmental burdens.

Energy Consumed: The impact of different window frame materials on overall energy costs can be evaluated by using a prototypical condominium project in three different U.S. climate zones. Thermal performance characteristics of wood and vinyl windows are presumed to be the same. Based on data and case studies from the Efficient Windows Collaborative ([www.efficientwindows.org](http://www.efficientwindows.org)), descriptions, U-values, and Solar Heat Gain Coefficients (SHGCs) are consistent for this comparison, using low-E clear double glass that is spectrally selective. SHGC measures how well a window stops the transmission of solar heat gain in a building. Lower numbers mean less solar heat gain. U-values and SHGCs are for the total window and frame.

Using the same glass, this analysis compares different window frame materials, aluminum frame with thermal break, aluminum-clad wood frame, and vinyl frame, for energy performance. Results may vary depending on specifications.

The prototype condominium is 10,000 sf, with 1,500 sf of glazing, and five condos of 2,000 sf each. Windows are located on all four building elevations, and include shading (interior shades, overhangs, and trees). Heating is by gas furnace, with air conditioning for cooling.

The analysis for a cold climate like Madison, WI indicates wood or vinyl frames save seven percent on annual energy costs over aluminum frames. The results are typical for buildings occupied 24 hours a day, such as assisted living facilities, apartments, condominiums, dormitories, and single-family homes. Office buildings and schools will have reduced heating loads due to internal heat generation from lighting, equipment, and higher densities of people. These buildings will have higher cooling loads and the percentage of savings may be lower.

A more temperate climate, like Kansas City, MO, indicated a seven percent savings in yearly energy costs with wood and vinyl frames. In the hot climate of Phoenix, AZ, wood or vinyl yields a six percent annual energy cost savings over thermally-broken aluminum frames. Savings over aluminum frames without thermal breaks are much higher.



At Burlington apartments in Portland, OR, Ankrom Moisan Associated Architects specified wood windows to meet the developer's energy-efficiency requirements more cost-effectively than aluminum.

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Recyclable: Aluminum and wood are typically recycled for various purposes. There is debate within the building industry about the feasibility of recycling vinyl windows. The Vinyl Institute claims that vinyl windows are recyclable, while a 1999 EPA report stated that most PVC products are disposed of either through landfills or incineration, with only a small percentage that are recycled, roughly three percent in Europe and less than 0.6 percent in the U.S.

Aluminum can be recycled, during manufacturing and before building demolition. Recovery of aluminum from demolition and replacement in the building industry is minimal compared to recovery from the consumer goods sector. Of the estimated 400 million pounds of aluminum potentially available, only 15 to 20 percent is recovered. According to the National Resources Defense Council, aluminum should be used in applications where high recycling rates can be achieved and where its unique properties are indispensable.

## Environmental Comparison of Window Framing Materials

Criteria	Aluminum	Wood	Vinyl
Source Material		+	
Renewable		+	
Recycled content	+	+	?
Embodied energy		+	
Pollution produced		+	
Energy consumed		+	+
Recyclable	+	+	?
Biodegradable		+	

“Aluminum frames cause the highest burden to the environment because of the dangerous pollutants release and high energy consumption during aluminum production. PVC contributes large amounts of poisonous pollutants throughout its life cycle, while wood window frames have the least environmental impact.”

***Source: Life Cycle of Window Materials – A Comparative Assessment, June 2002***

+ = favorable environmental impact

? = environmental impact uncertain

**Biodegradable:** Among aluminum, vinyl, and wood, only wood is biodegradable. Biodegradable materials can break down into the raw materials of nature and disappear into the environment.

A report studying life cycle assessment by USGBC, “Assessment of the Technical Basis for a PVC-Related Materials Credit for LEED,” (LEED Technical and Scientific Advisory Committee PVC Task Group, February 2007), concluded that aluminum window frames, with or without thermal breaks, are consistently the worst material relative to environmental impact when compared to the vinyl and wood alternatives reviewed.

Overall, studies from the U.S. and the U.K. analyzing the life cycle assessment of aluminum, vinyl, and wood window frames, based on production, energy consumption, environmental impact, and other factors, support the conclusion that wood window frames have the least environmental impact.

“Wood frame windows bring an organic quality to projects, which cannot be replicated by other types of cladding. They provide great LEED performance ratings, sustainable design, and

occupant comfort,” says Celeste Novak, AIA, LEED-AP, principal, En/Compass Architecture, Ann Arbor, Michigan.



In selecting resource-efficient windows for the Prairie Learning Center, OZ Architecture specified aluminum-clad wood windows with argon-filled, Low-E insulating glass and triple glazing with integral blinds.

Neal Smith Wildlife Refuge/Prairie Learning Center, Prairie City, IA. Oz Architecture

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## Conclusion

The USGBC’s LEED Green Building Rating System has become the benchmark against which to measure sustainable buildings in the U.S. The major LEED categories enable design professionals to analyze building project components and related issues that contribute to sustainability and environmental best practices.

Based on a detailed analysis of LEED categories, windows and doors can contribute to one prerequisite and up to 25 of the 69 points toward LEED certification. When comparing aluminum, vinyl, and wood frame windows, wood windows provide the greatest sustainability benefits and least environmental impact on the environment.

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