Greater Vision: Alternate Window Materials in Commercial Buildings

May 2005

Glass Options

Window assemblies consist of framing, glazing systems, hardware, finishes, sealants, and weather stripping. The first consideration is glass and glazing options. This is a key in calculating long-term cost because of its affect on energy efficiency and building operating expense.

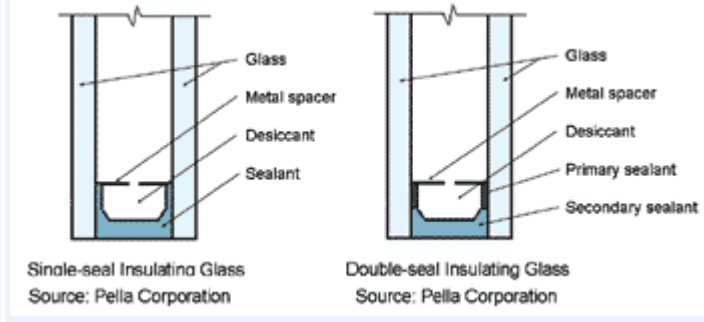
Design requirements, the size of the window openings, thermal performance, cost, sound transmission, maintenance, durability, shading options, weather conditions and local requirements all have a bearing on selection of the glazing system.

Wood-framed glazing complements the beautiful view of the woodlands at Lakeside Nature Center, Kansas City, MO, by International Architects Atelier.

In commercial structures, the two most commonly chosen systems are sealed insulating glass and dual glazed systems.

Sealed insulating glass consists of two glass panes separated by a perimeter spacer typically made of metal. The sealed space between the panes may be filled with an inert gas like argon to improve the U-value of the insulating glass unit (IGU). In a single-seal system the primary sealant is applied behind the spacer. In a double-seal system, the primary sealant seals the spacer to the glass on both sides, and the secondary sealant, which is applied behind the spacer,

provides the structural characteristics needed to hold the unit together. In both cases the sealant minimizes the potential for moisture intrusion and gas loss. However, when the seal in insulating glass fails, moisture appears on the internal surfaces, impairing vision through the glass and permanently damaging the insulating glass, which then must be replaced at a significant cost to the owner. Single-seal sealant systems often carry a five-year warranty against seal failure whereas double-seal systems typically come with a ten- to twenty-year warranty.



Single-seal Insulating Glass
Source: Pella Corporation

Double-seal Insulating Glass
Source: Pella Corporation

Dual glazing comprises two single glass panes set individually into a window frame of aluminum or wood. (Vinyl and fiberglass frames do not typically offer a dual glazing option.) Dual glazing relies on a gasket and vent system design to keep moisture out of the air space and from forming on internal glass surfaces. The space between panes of glass can vary in size to hold blinds or other shading devices and to buffer outside sound, temperature changes and wind. In most cases dual glazing systems offer a life cycle cost advantage over windows with sealed insulating glass since they are not subject to the seal failure commonly associated with insulating glass systems.

Wayland Union Middle School, Wayland, MI, by Design Plus, Inc., shows how dual glazing with between-the-glass window treatments reduces maintenance.

The table below shows a comparison of sealed insulating glass and dual glazing—at a quick glance, both offer similar advantages in terms of aesthetics, cost, and thermal performance. However, the IGU accommodates a wider range of fenestration types and larger glass sizes,

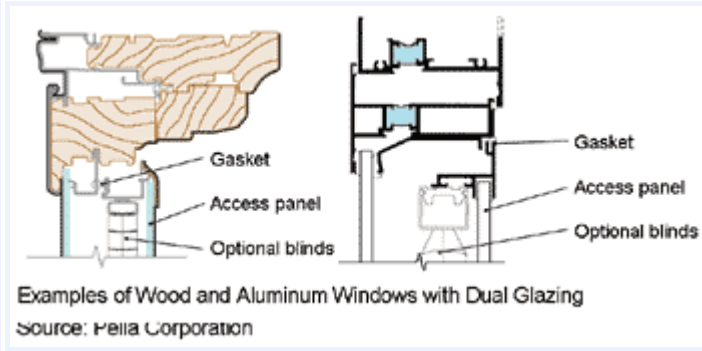
while dual glazing offers a longer life, easier re-glazing, between-glass options, less sound transmission, and better thermal performance when between-glass blinds are included.

Comparison of Dual Glazing and
Insulating Glass based on Selection Criteria

Glazing System Selection Criteria	Dual Glazing	Insulating Glass
Fenestration Type		+
Glass Size		+
Longevity	+	
Re-glazing	+	
Between-glass options	+	
Thermal Performance	=	=
Thermal Performance with blinds	+	
Cost	=	=
Aesthetics	=	=
Sound Transmission	+	

Both dual glazing and insulating glass units can accommodate between-glass options such as blinds and muntins. In a dual glazing system the interior glass panel is typically designed as an access panel, allowing blinds/shades to be serviced for maintenance/repair. However, when the blinds in an insulating glass unit break, the entire piece of insulating glass requires replacement.

When blinds are excluded, the difference in cost between a window with insulating glass and one with dual glazing is negligible. The initial price of a between-glass blind is slightly higher than a room-side blind of similar quality. However, between-glass blinds do not have the future life-cycle costs associated with room-side blinds (i.e. cleaning and replacement due to damage).



Examples of Wood and Aluminum Windows with Dual Glazing
Source: Pella Corporation

When comparing insulating glass to dual glazing, the only differing acoustic factor is the air space between the panes of glass. The larger air space associated with dual glazing results in less sound transmission through the window and a sound transmission class (STC) rating at least 15% better, with additional improvements in STC as the air space increases.

When sealed insulating glass is broken, the entire unit must be replaced. However, with the large air space between the panes in a dual-glazed window, it is uncommon for both to be broken simultaneously. When the exterior pane is broken, the interior pane remains intact and provides protection or vice versa.

Thermal Performance of Insulating Glass and Dual Glazing

Glass Type	Visible light transmission	Ultraviolet light transmission	Solar heat gain coefficient	U-value of total unit
Clear insulating glass	81%	56%	0.76	0.54
Clear dual glazing	81%	56%	0.76	0.50

The above table shows clear dual glazing offers a better total window U-value than clear insulating glass while all other values are the same. When closed blinds are added to the window, dual glazing with between-the-glass blinds offers an 18% improvement in total window U-value and a 43% improvement in solar heat gain coefficient (SHGC) over a window with room-side blinds.

In addition to using layers of glazing and controlling the properties of the spaces between them, the Web site www.efficientwindows.org suggests improving the energy performance of glazing products by changing the chemical composition or physical characteristics of the glazing material by adding a tint or by applying a low-emittance (Low-E) coating to the glazing material surface to reduce heat gain and glare.

Framing Materials

The next consideration is window frame material. The window frame must do several things. It should provide strength to withstand wind and other loads, drainage for water and accommodate weather stripping, glazing channels and rabbets, weep holes, internal gutters, screw bosses, concealed fasteners, flashings, drips, corner keys, thermal breaks, hardware, and frame accessories.

Properties of the framing material affect the thickness and weight of each window. A suitable material can be chosen from four available options: wood, aluminum, vinyl and fiberglass.

Each one has properties that make it more appropriate for certain applications.

Wayland Union Middle School, Wayland, MI, by Design Plus, Inc., shows how dual glazing with between-the-glass window treatments reduces maintenance.

Wood is one of the oldest building materials and has been the traditional frame material in all types of buildings primarily because it has been consistently and readily available and can be milled into many shapes to fit simple or complex designs. Wood-framed windows also can have an exterior cladding of vinyl or aluminum to increase weather-resistance while retaining an attractive wood finish on the interior.

Aluminum is a popular window frame material appreciated for its light weight and durability, but it has the disadvantage of high thermal conductance. This nonferrous metal is made from bauxite and cryolite and can be extruded into simple or complex frames. It is available in a variety of anodized and painted finishes. Aluminum is considered mostly for commercial and institutional

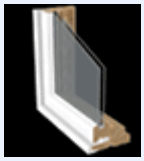
use and when manufactured with a high percentage of recycled content adds value in green building.

Vinyl (also known as polyvinyl chloride or PVC) is newer than wood or aluminum as a window frame material and is derived from fossil fuels. It offers good insulating values and has good moisture resistance. Some recent advances have improved dimensional stability and resistance to degradation from sunlight and temperature extremes. Vinyl is considered a residential material and because PVC formulations for windows are not consistent throughout the industry, quality and performance can vary.

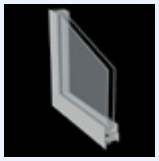
As window framing material, fiberglass (glass-fiber-reinforced polyester) is an emerging product. Fiberglass framing products were developed in the 1990s and currently are used in less than 2% of today's market. Fiberglass is a composite that can be pultruded into lineal forms. Because the material is stronger than vinyl, it can have smaller cross-sectional shapes and thus less area. It provides exceptional thermal stability, strength, and durability.

The Selection Process

Four window types are commonly used in commercial structures: double-hung, casement, fixed and awning. A double-hung window consists of two sashes operating in a rectangular frame with upper and lower halves able to slide up and down. A casement window swings open on side hinges. A fixed window has no operating sashes, and an awning window is similar to casement, but the sash is hinged at the top and always swings out.



Aluminum-clad wood



Aluminum with thermal break

Vinyl

Fiberglass

Source:www.efficientwindows.org

How Window Materials Meet Selection Criteria

	Wood	Aluminum	Vinyl	Fiberglass
Aesthetics	Warm, natural beauty; many finish options	Many finish options	Limited color options	Many color options
Energy Efficiency	Natural insulator	Natural conductor	Good insulator	Good insulator
Environmental Impact	Very low embodied energy; can be recycled	High embodied energy; can be recycled	Medium embodied energy; not recyclable	Low embodied energy; limited recyclability
Price	Medium to high first cost; low long-term cost	Medium to high first cost; low long-term cost	Low first cost; higher long-term cost	Low first cost; low long-term cost
Durability	High	High; but potential for thermal break failure	Low; cracks easily	High
Maintenance	Interior wood surfaces may need refinishing; scratches can be repaired	Low; not scratch resistant	Low; may require early window replacement	Low; high scratch and dent resistance

Aesthetics

The choice of materials is influenced by the architect's perspective and the project design intent. Several things must be considered: scale and proportion, sightlines, relationship to other interior finishes, frame profiles, and glass types. Hardware and location of window treatments (room side or between-glass blinds) also influence the choice of frame material.

Of the four framing materials, wood is unique because it allows different finishes for the interior and exterior and provides a warmth and natural beauty not offered by the other materials.

Aluminum offers a broad selection of anodized and painted finishes that typically are the same on both sides. Aluminum can be combined with wood in an aluminum clad wood frame that offers the warmth and natural beauty of wood on the interior and the durability of aluminum on the exterior.

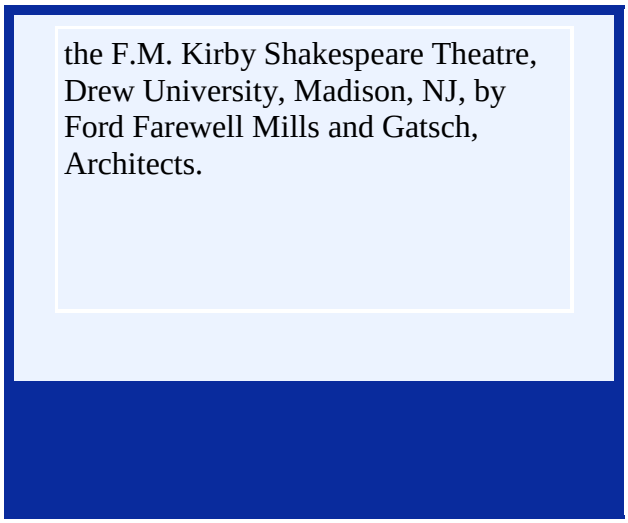
Vinyl framing offers few color choices and has the same finish on both sides. Medium to dark colors are especially limited. Some manufacturers offer surface treatments such as laminates or other coating options to increase color selection and surface appearance.

Fiberglass has high design flexibility with many color options. The material is typically painted the same color on both sides but offers the potential for different colors on the exterior and interior.

Energy Efficiency

The energy efficiency of the windows has a significant impact on the overall annual operating costs of a building. To obtain the best energy efficiency from a window three factors must be evaluated: thermal performance, condensation resistance and occupant comfort. Additionally, because installation can affect window performance, the manufacturer's installation instructions should be evaluated and followed for optimum performance.

Wood windows optimize design performance and budget flexibility at



the F.M. Kirby Shakespeare Theatre, Drew University, Madison, NJ, by Ford Farewell Mills and Gatsch, Architects.

To compare thermal performance look at the R-values and U-values. The R-value measures resistance of glazing material or fenestration assembly to heat flow. Materials with higher R-values have higher resistance to heat flow and are better insulators. The U-value measures the rate of non-solar heat loss or gain through a material and may be expressed for the glass alone or the entire window including frame and spacer material. The lower the U-factor, the greater a window's resistance to heat flow and the better its insulating value.

Choice of materials has a bearing on both these factors. For example, in Chapter 30 of the 2001 ASHRAE Fundamentals Handbook, the addition of a thermal break in an aluminum frame improves the U-value from 1.92 to 1.13. An aluminum-clad wood frame further improves the frame U-value from 1.13 to 0.51.

The handbook also indicates that total Unit U-values for the entire window include both the frame and glass. The range for aluminum windows with thermal breaks is from 0.35 (triple glazing with low-E coatings) to 0.64 (double glazing with clear glass).

For aluminum-clad wood windows the range is from 0.25 (triple glazing with low-E coatings) to 0.53 (double glazing with clear glass). The glass is the same so the difference in U-values is a result of changing frame material.

The National Fenestration Rating Council (NFRC) is a reliable source for determining window energy properties and comparing products. NFRC rates window units for U-factor, SHGC, visible light transmittance (VT), and air leakage (AL).

Another factor that affects window thermal performance is air infiltration. Air leakage heat loss and gain occur by infiltration through cracks in the window assembly. This is indicated by an AL rating expressed as the equivalent cubic feet of air passing through a square foot of window area. The lower the AL, the less air will pass through cracks in the window assembly. Select windows with an AL rating of 0.30 cfm/sq ft or less.

Resistance to condensation also is important. Condensation on window frames can damage interior windowsills, finishes and eventually walls and floors. Specifying products and design conditions that regulate surface temperatures and moisture in the air will minimize potential for condensation.

Materials with greater resistance to condensation also provide greater comfort to occupants seated near windows, and occupant comfort has a direct impact on worker productivity.

Wood is considered the best performer from a thermal point of view. It is a natural insulator with excellent resistance to condensation and a high degree of thermal comfort.

Aluminum is a natural conductor and therefore has poor energy efficiency and low resistance to condensation. Aluminum's R-value is minimal and raises the overall U-factor of a window unit. In cold climates, an aluminum frame can become cold enough to condense moisture or frost on the inside surfaces.

A desirable combination for thermal performance and comfort is an aluminum-clad wood window. This alleviates differences in exterior and interior frame temperatures, offering resistance to condensation, greater thermal comfort and lower annual energy costs than thermally-broken aluminum windows.

The average annual savings from the use of aluminum-clad wood windows is fairly consistent across the United States: 27% to 31% compared to single-glazed aluminum windows without thermal breaks; 6% to 9% compared to thermally-broken aluminum windows.

Vinyl has the same thermal efficiency as wood and in terms of thermal performance vinyl frames are comparable with wood. However, vinyl's expansion and contraction encourages air and water infiltration which increases maintenance and damage issues.

Fiberglass offers thermal efficiency similar to wood and the lowest expansion and contraction rates of all four materials. Less expansion ensures a consistent bond between sash and glass and reduced energy costs as well as less stress on joints for greater durability.

Environmental Impact of Materials

The choice of windows can add value to a structure and the environment. The most commonly used evaluator of a structure's environmental impact is the U.S. Green Building Council's LEED® (Leadership in Energy and Environmental Design) Green Building Rating System. This guide for designing, constructing, operating, and certifying buildings is based on accepted energy and environmental principles.

LEED's measurement standard follows a point system. The four levels of LEED certification and required points for each are:

Certified 26 - 32 points

Silver	33 - 38 points
Gold	39 - 51 points
Platinum	52+ points (69 possible)

The points are earned within six categories. The five environmental categories (not including Innovation and Design Process) are divided into credits. One or more points are available within each credit, and points are achieved by meeting specified requirements.

- Sustainable Sites: 8 credits, 14 points
- Water Efficiency: 3 credits, 5 points
- Energy and Atmosphere: 6 credits, 17 points
- Materials and Resources: 7 credits, 13 points
- Indoor Environmental Quality: 8 credits, 15 points
- Innovation: 4 points

Involving a LEED Accredited Professional in the process adds another point.

LEED uses performance-based requirements, so most building products will only contribute to achieving LEED points, not credits. To meet these, products with desired attributes should be specified.

Vinyl window frames offer the same thermal efficiency as wood.
Courtesy of Pella Corporation

Currently, LEED-NC (New Construction and Major Renovations/Additions) Version 2.1 involves window selection for commercial properties. USGBC expects to release Version 2.2 by Fall 2005.

Windows and doors can contribute to one prerequisite and up to 26 points in LEED-NC. Windows may contribute one point in the Sustainable Sites category under Light Pollution Reduction, dealing with light trespass from buildings. Although most of the credit revolves around outdoor lights, it includes interior light trespass through windows at night. Proper use of window treatments can contribute to this credit if they reduce glare or direct light shining onto neighboring property, streets, or night sky.

In the Energy and Atmosphere category, windows can contribute to 1 prerequisite and up to 13 points. Prerequisite 2—Minimum Energy Performance requires the building comply with ASHRAE/IESNA 90.1-1999 or the local code, whichever is more stringent. Windows can contribute to meeting the standard's building envelope requirements based on their energy efficiency, including low U-values, low air infiltration rates and low SHGC.

Windows can earn points in Credit 1—Optimizing Energy Performance. Up to 10 points are available with this credit and increase as energy costs decline so the window's energy efficiency is critical in maximizing this point category.

Points also can be earned in Credit 1—Technologies and Strategies for strategic placement of windows for natural ventilation, minimal undesirable air infiltration, maximum day lighting and minimum heat gain. Appropriate glazing to optimize natural lighting, heating and cooling also is point-worthy. The LEED Reference Guide notes only permanent interior shading devices such as between-glass blinds qualify for points.

Window material's content can earn points in Credit 4—Recycled Content. Aluminum, glass and wood can contribute to two points because they are recyclable materials and have recycled content. Additional points can be earned in Credit 5—Local/Regional Materials if the windows are made within 500 miles of the project site and another point can be added if a minimum of 50% of the building materials and products are extracted, harvested or recovered within the 500-mile guideline.

In the major category of Indoor Environmental Quality, windows can contribute up to 6 points. In Credit 2—Increase Ventilation Effectiveness, consider using operable windows to provide natural ventilation. Operable windows also can earn points in Credit 6—Controllability of Systems if an average of one operable window and one lighting control zone per 200 square feet are specified for all regularly occupied areas within 15 feet of the perimeter wall.

Windows can contribute to Credit 4.2—Low-Emitting Materials (Paints), if windows with low VOC paints and coatings for field-finishing of interior wood surfaces are chosen. In Credit 4.4—Low-Emitting Materials (Wood), eliminating urea-formaldehyde in composite wood products will contribute to this credit.

In Credit 8—Daylight and Views, windows earn credits for day lighting building interiors and views. Building orientation, window size and spacing, window placement for direct line of sight to exterior, glass selection, shading devices, light shelves, courtyards, atrium and window glazing should all be considered to earn points in this credit.

If the project is not going to be submitted for LEED certification, the program's requirements can be used as guidelines in evaluating window frame material for environmental impact.

The Green Guide to Specification also provides evaluation methods for various window options.

Environmental Impact of Window Materials

Window Material	Rating
Softwood preserved	A
Hardwood framed	A
Aluminum clad-wood	B
Aluminum	B
Vinyl	C

Source: The Green Guide to Specification, 3rd Edition

A= low environmental impact; B = middle range; C = high environmental impact. The rating is a summary of the overall impact of 12 environmental factors as well as cost, recycled content, recyclability, current recycling effort and typical replacement time.

Of all four materials, wood has the lowest embodied energy. It takes only 3,770 BTUs of energy to produce a pound (BTU/lb) of wood. Wood frames also are recyclable if and when they are no longer in use and are biodegradable if the products are disposed of into the environment. Additionally, the softwood used for window frames is obtained from rapidly renewable resources; the net volume of wood in U.S. forests is increasing because of sustainable harvest techniques.

Aluminum contains bauxite a non-renewable resource and takes the most energy (103,500 BTU/lb.) to produce from raw materials. But aluminum extruded from recycled materials uses only 20,700 BTU/lb. Aluminum frames also are recyclable when their use has ended.

Vinyl depends on oil resources so it is not as environmentally acceptable. Vinyl window frame material also does not have recycled content and takes 36,500 BTU/lb to produce. It is unclear whether vinyl is recycled or recyclable. The Vinyl Institute indicates vinyl window frames are

recyclable, but the U.S. EPA states only a small percentage of vinyl—0.6% in the United States and 3% in Europe—is recycled.

Also, the USGBC is re-evaluating its position on vinyl. During early LEED development a credit was proposed for the avoidance of vinyl in building products. Questions have been raised that available science shows no grounds to support this exclusion of vinyl. The USGBC Technical and Scientific Advisory Committee has begun a comprehensive study on the matter and intends to publish its final report in late 2005.

Fiberglass has very low embodied energy. It is a natural insulator with low expansion/contraction rates and thus maintains dimensional stability year round. Fiberglass also has self-extinguishing capabilities in case of fire and does not emit toxic fumes.

Price

Determining the cost of window options can be a difficult task at best. Prices vary by manufacturer and specific needs. But the most important comparison is long-term cost. Total initial cost per square foot is based on many factors including performance, size, glass specifications (e.g. low-E or clear glass), and interior and exterior frame colors (standard or custom).

But maintenance/repair needs and energy/operating costs must be added to first costs to calculate the long-term cost of the building. Window style, accessibility for maintenance and upkeepof framing material must be part of this calculation. For example, between-the-glass options for blinds and shades can offer long-term savings on maintenance and energy usage.

Average Price Comparisons

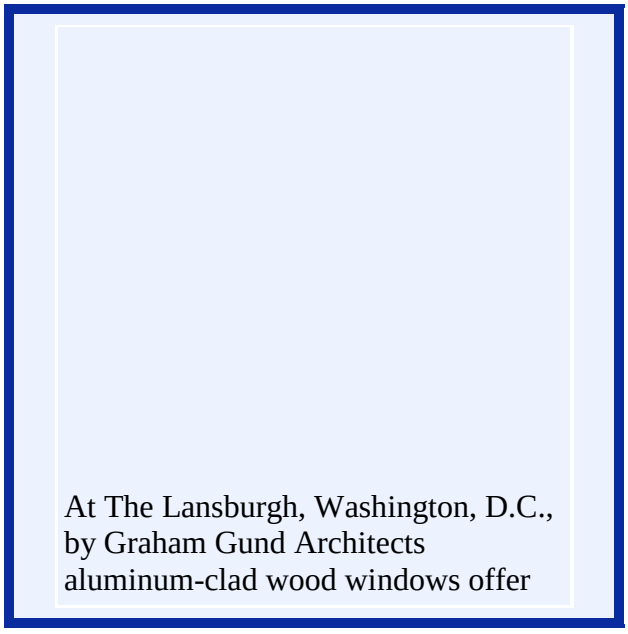
Based on a quantity of 300 windows, not installed,
with clear insulating glass, standard hardware without screens.

Frame & Sash Material	Exterior Finish	Interior Finish	Cost per Window
Double Hung - 3 feet wide by 5 feet high			
Aluminum with thermal break	Clear anodized	Clear anodized	$276
Fiberglass	Fiberglass	Fiberglass	$198
[illegible]	[illegible]	[illegible]	[illegible]

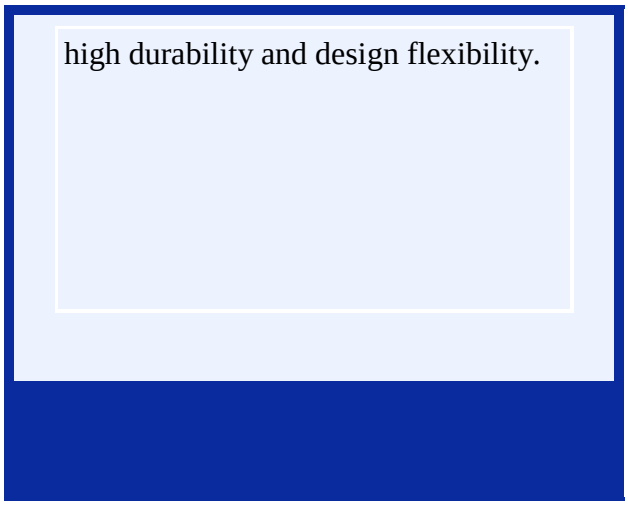
clad wood	color	2 top coats of paint	
Vinyl	Vinyl	Vinyl	$174
Fixed Casement - 2 feet wide by 5 feet high			
Aluminum with thermal break	Clear anodized	Clear anodized	$197
Fiberglass	Fiberglass	Fiberglass	$188
Aluminum-clad wood	Standard color	Prime and 2 top coats of paint	$216
Vinyl	Vinyl	Vinyl	$194

Sources: R.S. Means Building Construction Cost Data and Pella Corporation

In comparing life cycle cost, aluminum window frames can be lower in repair and maintenance costs. In most cases dual glazing systems, whether in wood or aluminum windows, offer a life cycle cost advantage over windows with sealed insulating glass. Choice of color and coating on an aluminum frame also can affect cost.



At The Lansburgh, Washington, D.C., by Graham Gund Architects aluminum-clad wood windows offer



In first cost, wood and aluminum are comparable. Generally initial costs for operable aluminum-clad wood windows offer a lower price point than aluminum windows. For storefront applications, costs are comparable. In curtain walls and window walls aluminum systems typically cost less than wood.

Vinyl offers short-term savings because of its initial low cost, but the long-term cost of vinyl is higher because vinyl's expansion and contraction can cause more repairs and potential earlier replacement of windows due to frame failure.

Fiberglass is priced lower than aluminum and is competitive with vinyl. Fiberglass' superior durability should be factored into long-term costs.

Durability

When determining a structure's windows, consider the building owner's or developer's intent for the project. How long do they expect the building to last? How well will the owner maintain the structure? How will weather conditions affect the structure?

The durability of any material can be proven by how it reacts over time to weather extremes, impact and damage caused by nature or human acts. The thermal break of a window also is a key consideration in durability.

With wood windows, a thermal break is natural because of wood's inherent properties, making it a more stable option. But the durability of wood is sometimes misunderstood because in certain climates it can be more susceptible to rot. According to the Window and Door Manufacturers Association (WDMA): "Wood stands the test of time. It doesn't naturally decay as many people believe and indeed has been found nicely preserved in 2,000-year-old structures."

Wood-frame windows on historic buildings have lasted for centuries—a testimony to wood's incredible durability. Prior to the 1920s, wood was virtually the only window frame material available. Today, the most common reasons to replace wood-frame windows are not because of structural or material failure, but rather to:

- Replace single glazing with more efficient dual glazing;
- Improve weatherstripping to reduce air infiltration; or
- Provide exterior aluminum cladding to eliminate exterior repainting.

Aluminum windows are perceived as highly durable. The only weakness is in the construction of the thermal break, which is commonly engineered using a polyurethane material that is susceptible to shrinking and cracking over time. This can eventually cause glazing failure, increased air and water leakage, and a general degradation of the window unit's structural integrity.

Architects concerned about thermal break performance can reference the test method and performance requirements outlined in The American Architectural Manufacturers Association (AAMA) publication 505-98, "Dry Shrinkage and Composite Performance Thermal Cycling Test Procedure".

Vinyl resists abrasion and moisture and withstands rust and corrosion, but generally is less durable than other window frame materials. According to the WDMA, however, efforts have been made to make vinyl a more long-lasting material. The WDMA Hallmark Certification program focuses on stabilizing manufacturers' formulation compounds by requiring long-term weathering tests for color retention and certain mechanical properties. This has helped upgrade the quality of vinyl and reduce the number of manufacturers making less-than-quality vinyl material.

Aluminum-clad wood windows offer low-maintenance exterior and warm, rich interior at Vollum Institute for Advanced Biomedical Research, Portland, OR, by Zimmer Gunsul Frasca Partnership.

Fiberglass is a strong and durable window frame material. It is nine times stronger than vinyl and twice as strong as aluminum in tensile strength. It also offers high impact and scratch resistance and low thermal expansion.

Maintenance

For most buildings maintenance costs represent the highest percentage of long-term costs at 67% of the life cycle cost; energy costs are 16% and initial costs are 17%. Therefore, all possible window maintenance activities must be evaluated in choosing window materials. These are: washing the glass, cleaning the window coverings, replacing broken parts, re-finishing and repairing interior surfaces, replacing broken glass or failed insulating glass.

Specifying between-the-glass blinds and shades in wood or aluminum windows can reduce maintenance on window treatments because they are located between the panes of glass where they are protected from dust and damage. Windows with interior access for washing the exterior provide easier, faster cleaning, which also can reduce maintenance costs.

The cost of replacing broken parts is comparable for wood, aluminum, vinyl, and fiberglass windows unless the manufacturer that supplied the original windows is no longer in business. Then replacement parts such as double-hung balances and casement hinges and cranks are not available and the only option is to replace the entire window.

Choice of framing materials also affects maintenance. Wood does not need frequent refinishing if the initial finish is high quality.

When the interiors of wood windows are finished properly (three coats) the finish can last up to 25 years or more. Typically, stain and two coats of varnish last longer than paint. Additionally, the finish on a wood frame can easily be repaired to keep a neat, clean appearance or changed to match new interior needs.

As an exterior material, aluminum offers very low maintenance, however, any scratches or damage to the interior finish cannot be easily repaired. Because aluminum frames are not typically re-finished during the life of the windows, aluminum may offer a cost advantage.

Vinyl offers a low maintenance finish, but the material has low durability because of its sensitivity to temperature changes. Over the long-term, this can cause other maintenance problems related to air and water leakage and operation issues.

Fiberglass offers low maintenance and its scratch resistance is six times better than vinyl. A powder-coat paint finish on fiberglass is quite durable and easily withstands scratching and denting.

Outlook

The variety of available options for windows continues to grow and enhance possibilities for more durable, efficient systems to meet many design needs. The growth of the green building movement has increased awareness of using natural resources wisely and influenced product development. The commercial market is leading this trend and windows can play a significant role in saving energy during the life of the building. Decisions made now in the choice of

window materials will affect not only the daily comfort of building occupants but also the resources used to operate and maintain the building.

Case Studies

Blending aesthetics and energy efficiency

Visitors enter the Lakeside Nature Center in Kansas City, MO, through a single-story cast-in-place concrete wall that offers little clue to what lies beyond. Once inside, they are greeted with a view of lush woodlands, framed by floor-to-ceiling glazing rising up to 28 feet. Daylight from clerestory windows reinforces the illusion of being in the woods by simulating diffused light penetrating through a forest canopy. Transferring loads from the extensively overhung roof to the cedar columns without deflecting and breaking glazing was a major design challenge for International Architects Atelier as were the large spans of glazing and multiplicity of shapes and sizes.

Creating beauty with low maintenance

At the Vollum Institute for Advanced Biomedical Research in Portland, OR, architects Zimmer Gunsul Frasca (Portland, OR) chose to make wood a major interior design element. Chairs, paneling, trim, and window frames are all made of wood. For the windows, aluminum-clad wood was chosen for a low maintenance aluminum exterior and a warm, rich wood interior with durability and color flexibility. The wood blends with interior furnishings and trim and offers a warm, less institutional look. Plus, between-the-glass blinds reduce maintenance costs associated with cleaning and replacement of window treatments.

Zimmer Gunsul Frasca Partnership chose aluminum-clad wood windows with between-the-glass blinds for beauty and low maintenance at the Vollum Institute for Advanced

Biomedial Research, Portland, OR.

High design flexibility at low cost

High cost is not necessary to achieve great design. Phillips Place in Charlotte, NC, offers an example. Designed by LS3P Associates Ltd., it consists of one hotel, four restaurants, and 24 retail shops including Waverly Home, Smith & Hawken, Restoration Hardware, and Dean & Deluca. Pricing for wood windows for the center was competitive with aluminum windows so the developer chose aluminum-clad wood windows and doors with a burgundy exterior and low-E glass. The architect and developer most appreciated the wood windows for the flexibility that allowed tenants to finish the interior of the windows to match the design of their stores.

For example, Restoration Hardware and Cradle & All painted the windows different shades of white; Dean & Deluca painted the windows light gray; Smith & Hawken painted the windows a darker bluish gray and stained the doors.

Competitively priced aluminum-clad wood windows allowed tenants to match store interiors at Phillips Place, Charlotte, NC, by LS3P Associates Ltd.

Achieving environmental goals—beautifully

IslandWood, an interactive learning environment on Bainbridge Island, WA, helps children and communities understand how their actions affect the environment.

Windows in the complex are positioned to permit maximum air circulation and natural daylighting. Operable skylights provide additional natural airflow and light. The high performance wood windows are clad in aluminum to protect the exterior from the elements, reduce maintenance and provide a beautiful interior; the frames and glass have recycled content. These and other techniques helped IslandWood earn a LEED Gold Certification from the USGBC while being chosen one of the Top Green Projects for 2002 by AIA's Committee on the Environment.

Aluminum-clad wood windows at Island Wood, Bainbridge Island, WA, by Mithun, are positioned for maximum airflow and light.

Sources:
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www.efficientwindows.org
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