Electrochromic Glazing
Dynamic Control of Solar Energy

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SageGlass

SAINT-GOBAIN

Program Registration

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Learning Objectives

At the end of this program, participants will be able to:

- Analyze the impact of traditional solar control solutions, their associated energy penalty and contrast with the use of dynamic glazing.
- Explain the energy and environmental benefits of electrochromic glass and discuss key control strategies for maximum energy conservation.
- Examine the human factors benefit with electrochromics and discuss how durability improves sustainability.
- Understand key aspects of design for incorporating and specifying electrochromic glass to achieve maximum performance and potential contribution to LEED points.

Course Outline

Section 1: Electrochromic Glazing: The Power of Glass Without the Energy Penalty

Section 2: Energy and Performance Comparisons

Section 3: Sustainability and Human Factors

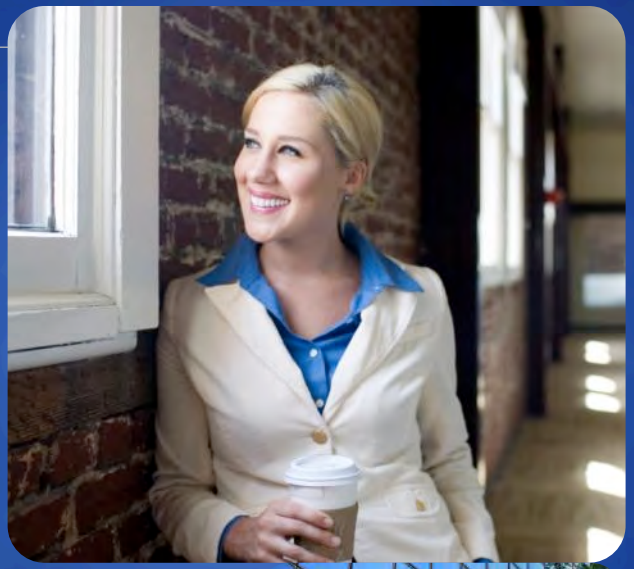
Section 4: Electrochromic Glazing Design Considerations

Section 1: The Power of Glass

Why Do We Use Glass?

Windows:

- Add architectural detail
- Provide a view and connection to the outdoors
- Create a more pleasant environment for building occupants



The Power of Glass

People love glass.

- Windows provide light, views and connection to the outdoors.
- Numerous studies confirm what most people know instinctively: people feel better and perform better in spaces where there is abundant daylight.

However…

Windows have a major impact on energy use – mostly negative.

- In a typical office building, 65% of total energy use is for lighting, heating and cooling.

Problems with Windows

- Heat gain
- Glare
- Energy use

The Conventional Solutions

- “Static” glass
- Interior blinds and shades
- Exterior shades

Expensive

Ineffective

Block view and connection to outdoors

Ongoing maintenance and repair

“Embedded carbon” issues

Dynamic Glazing Options

SPD

Suspended particle device, operating with 110VAC <15A

Powered stage is clear and tinted is off.

Laminate form, organic based compounds.

LCD

Liquid crystal device, operating with 110VAC <15A

Powered stage is clear and translucent is off.

Laminate form, organic based compounds.

Photochromic

Ultra violet light is absorbed by the materials and that absorption results in tinting based on the solar intensity.

Passive system, no electrical controlling capabilities.

Laminate form, organic based compounds.

Dynamic Glazing Options

Thermochromic

Heat is absorbed by the materials and that absorption results in tinting with intensity increasing as heat and pressure increase.

Passive system, no electrically controlling capabilities

Laminate form, organic based compounds.

Electrochromic

Thin film technology that tints on demand, <4VDC & <10mA.

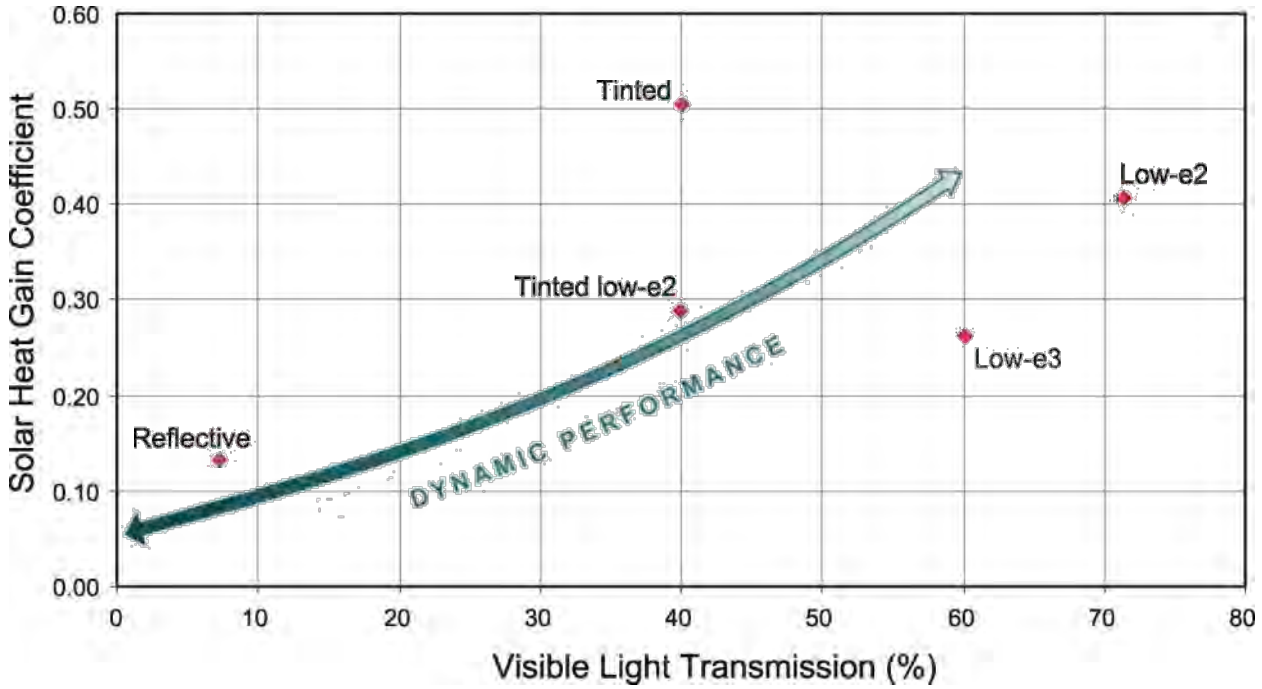
Powered stage is tinted, clear is off.

Series of ceramic and metallic films deposited onto glass surface, in-organic solution impervious to UV, high temperature and pressure gradients.

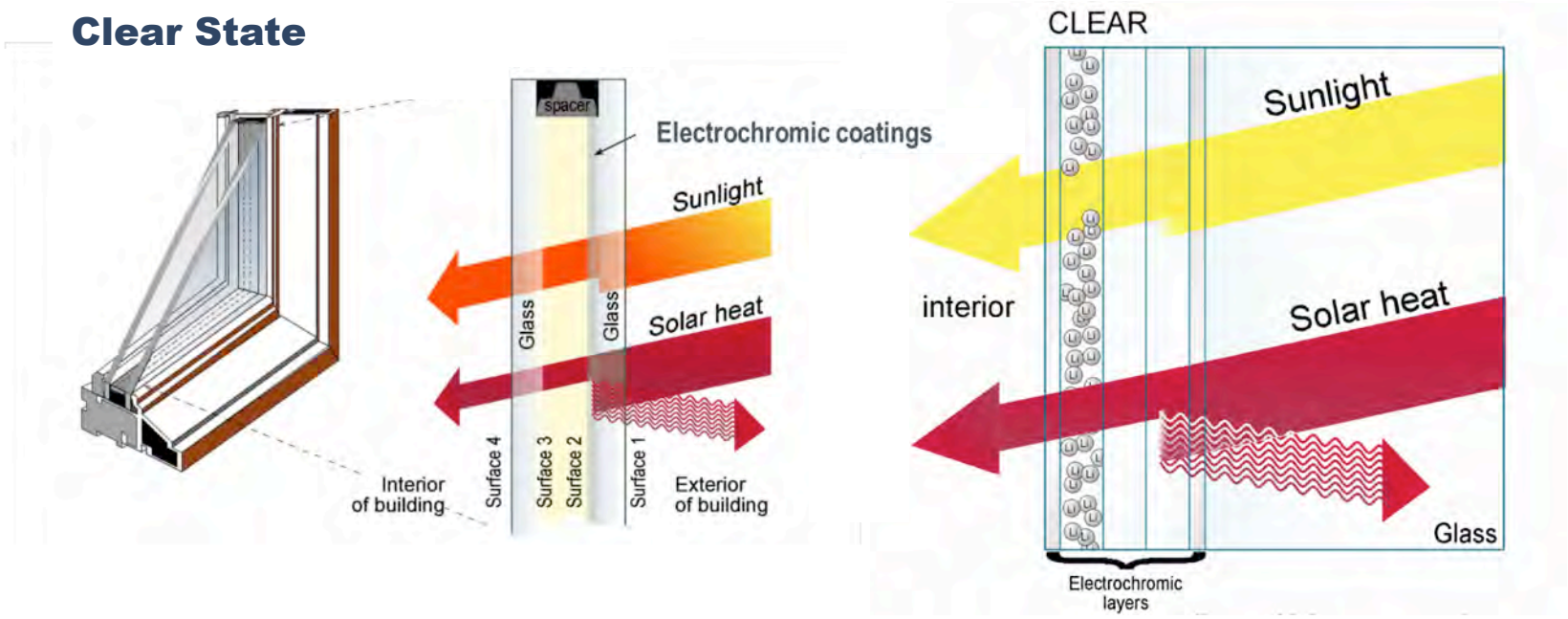
Electrochromic Focus

- Controllable
- Drives occupant comfort and energy efficiency
- Maintains view and connection to the outdoors
- Durable
- Energy Efficient
- Aligns with current IGU installation

Electrochromic Dynamic Range



Product Technology – How Electrochromic Glass Works



Up-front Cost Comparison

Conventional Solutions

Electrochromic Glass

Increased HVAC

Sunshades

Low-e IGU

Automated Blinds

EC Glass

Section 2: Energy Performance

Impact on Performance

Lawrence Berkeley National Lab, CA

- Energy & Human Factors Evaluation

Energy Results

- Up to 20% cooling energy savings
- Up to 60% reduction in lighting
- Up to 30% reduction in peak demand

Human Factors Results

Employees greatly preferred to be in the room with Electrochromic windows vs. static glass

EC Glass Energy Performance

DoE2.1 Building Simulation Model

- 8 story office building
- 160,000 square feet floor space
- 37,500 square feet window area
- Multiple climate zones
  - Minneapolis
  - Washington, DC
  - Phoenix

Energy Performance Results

	Percent Annual Energy Savings			Percent Peak Demand Reduction (kW)		
EC Double Pane *Compared to:*	**MN**	**DC**	**AZ**	**MN**	**DC**	**AZ**
Single-Pane Clear	*45%*	*45%*	*46%*	*40%*	*35%*	*39%*
ASHRAE 90.1-2007	*21%*	*22%*	*22%*	*24%*	*18%*	*14%*
EC Triple Pane *Compared to:*						
Single-Pane Clear	*56%*	*53%*	*n/a*	*45%*	*41%*	*n/a*
ASHRAE 90.1-2007	*37%*	*34%*	*n/a*	*29%*	*23%*	*n/a*
Static Triple	*14%*	*16%*	*n/a*	*26%*	*21%*	*n/a*

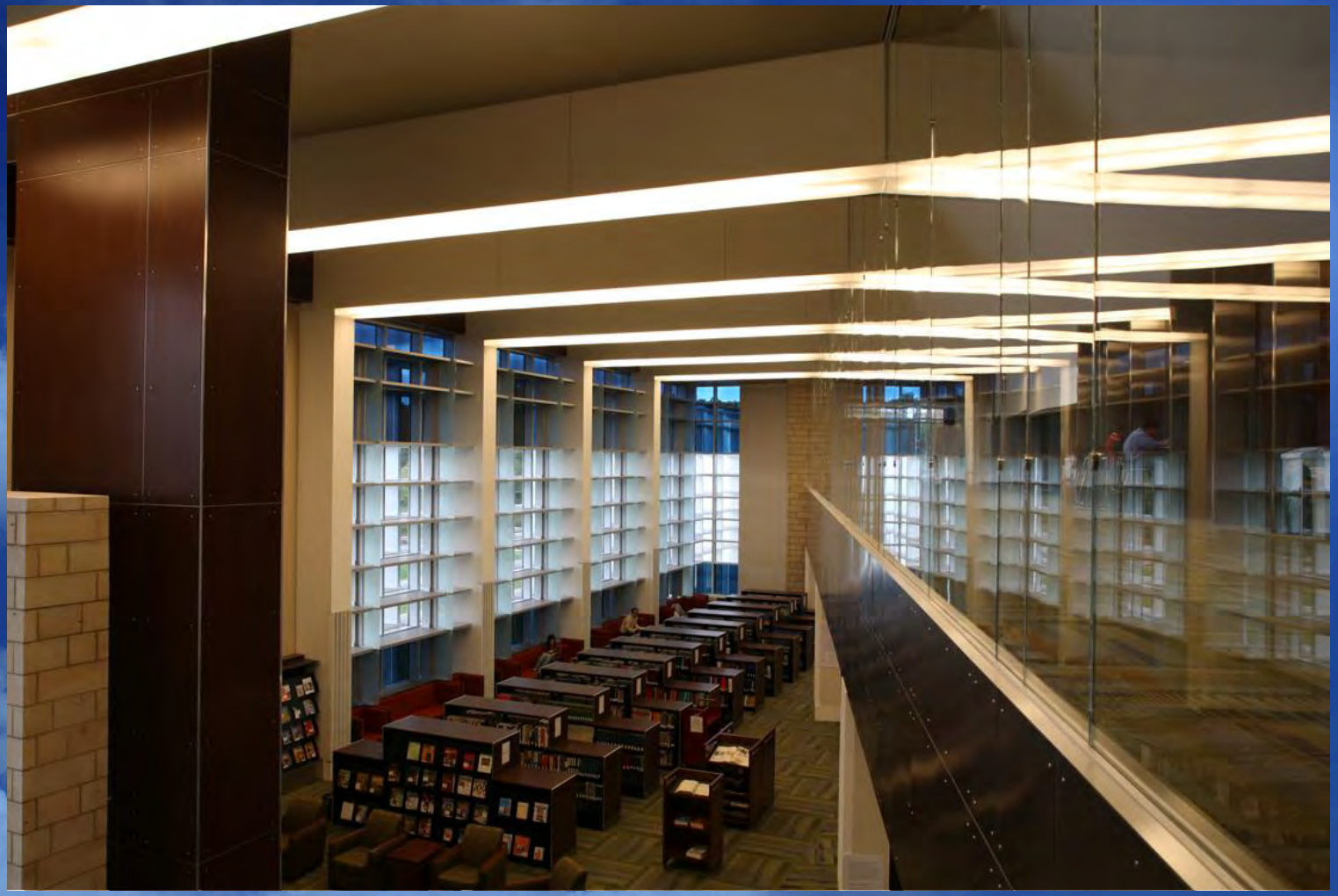
Energy and Operating Cost Summary

- Reduces energy use by up to 20%
- Lowers peak demand by up to 30%
- Lowers lighting costs by up to 60%
- Can reduce HVAC sizing by up to 25%
- Eliminates need for blind / shade maintenance

20%

30%

Section 3: Sustainability and Human Factors

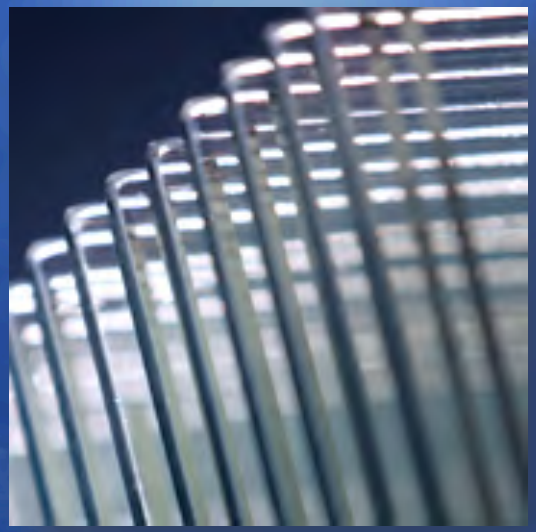


Key Factors of Sustainability

Controlling glare improves occupant comfort and productivity, and increases the effectiveness of daylighting strategies.

Controlling solar radiation eliminates embedded costs of manufacturing, transporting, maintaining, replacing and disposing of large amounts of interior materials otherwise damaged by fading.

Durability of the window means that maintenance and replacements costs of the Solar Control Solution are reduced.



Controlling Glare

Discomfort due to temperature or glare have a proven negative impact on occupant comfort and productivity.

In a world of technology with its multiple reflective screens, glare is a significant problem in the workplace.

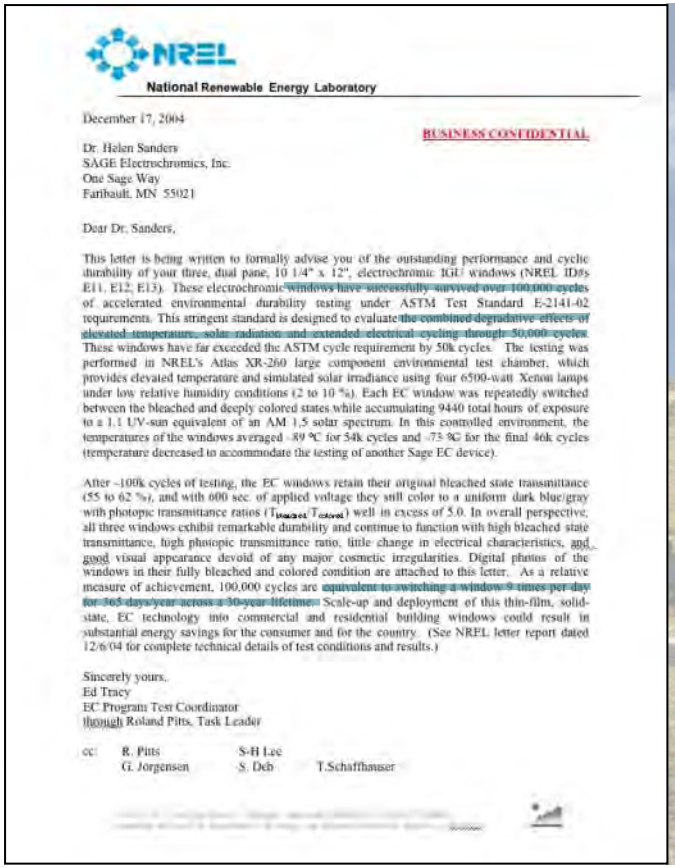
But in addition, glare has a significant negative impact on energy use due to increased lighting costs.

Controlling Solar Radiation: Fading Protection

Glass Type	Tdw-K	Tdw-ISO
Clear Glass	45%	30%
Low-E2	77%	52%
EC Glass (clear state)	82%	62%
EC Glass (tinted state)	98%	97%

- Tdw - K: Weighted transmission of the sun's energy that causes fading using the Krochmann Damage Function (300 - 500nm)
- Tdw - ISO: Weighted average of the sun's energy that causes fading using a function developed by the International Commission on Illumination (300 - 700nm)
- Data from Lawrence Berkeley National Laboratory's Window 5.2 software

Durability



NREL

National Renewable Energy Laboratory

December 17, 2004

BUSINESS CONFIDENTIAL

Dr. Helen Sanders
SAGE Electrochromics, Inc.
One Sage Way
Faribault, MN 55021

Dear Dr. Sanders,

This letter is being written to formally advise you of the outstanding performance and cyclic durability of your three, dual pane, 10 1/4" x 12", electrochromic IGU windows (NREL ID#s E11, E12, E13). These electrochromic windows have successfully survived over 100,000 cycles of accelerated environmental durability testing under ASTM Test Standard E-2141-02 requirements. This stringent standard is designed to evaluate the combined degradative effects of elevated temperature, solar radiation and extended electrical cycling through 50,000 cycles. These windows have far exceeded the ASTM cycle requirement by 50k cycles. The testing was performed in NREL's Atlas XR-260 large component environmental test chamber, which provides elevated temperature and simulated solar irradiance using four 6500-watt Xenon lamps under low relative humidity conditions (2 to 10 %). Each EC window was repeatedly switched between the bleached and deeply colored states while accumulating 9440 total hours of exposure to a 1.1 UV-sun equivalent of an AM 1.5 solar spectrum. In this controlled environment, the temperatures of the windows averaged ~89 °C for 54k cycles and ~73 °C for the final 46k cycles (temperature decreased to accommodate the testing of another Sage EC device).

After ~100k cycles of testing, the EC windows retain their original bleached state transmittance (55 to 62 %*t*, and with 600 sec. of applied voltage they still color to a uniform dark blue/gray with photopic transmittance ratios ($T_{bleached}/T_{colored}$) well in excess of 5.0. In overall perspective, all three windows exhibit remarkable durability and continue to function with high bleached state transmittance, high photopic transmittance ratio, little change in electrical characteristics, and good visual appearance devoid of any major cosmetic irregularities. Digital photos of the windows in their fully bleached and colored condition are attached to this letter. As a relative measure of achievement, 100,000 cycles are equivalent to switching a window 9 times per day for 365 days/year across a 30-year lifetime. Scale-up and deployment of this thin-film, solid-state, EC technology into commercial and residential building windows could result in substantial energy savings for the consumer and for the country. (See NREL letter report dated 12/6/04 for complete technical details of test conditions and results.)

Sincerely yours,
Ed Tracy
EC Program Test Coordinator
through Roland Pitts, Task Leader

cc: R. Pitts S-H Lee
G. Jorgensen S. Deb T.Schaffhauser

National Renewable Energy Laboratory

ASTM Test Standard E-2141-06 evaluates:

"...the combined degradative effects of elevated temperature, solar radiation and extended electrical cycling through 50,000 cycles..."

Electrochromic Glass "... windows successfully survived over 100,000 cycles ..."

"...equivalent to switching a window 9 times per day for 365 days/year across a 30-year lifetime."

Sustainability and Human Factors

The qualities that make electrochromic glazing sustainable also contribute to the comfort and performance of the building's occupants.

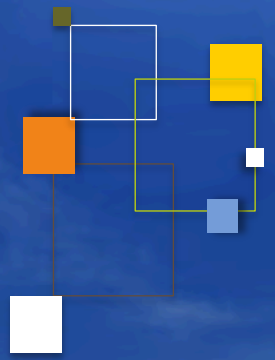
Human Factors

- Maintains occupants' view and connection to outdoors
- Harvests natural light
- Improves comfort
- Eliminates glare helping to improve employee productivity and satisfaction

Section 4: Design

EC Glass Design Features

- Double or Triple pane construction
- Broad control options
- Variable tint
- Zoning
- Superior fading protection
- Supports LEED
- Familiar installation



EC Control Systems

Simple switch

Automation using manufacturer controls

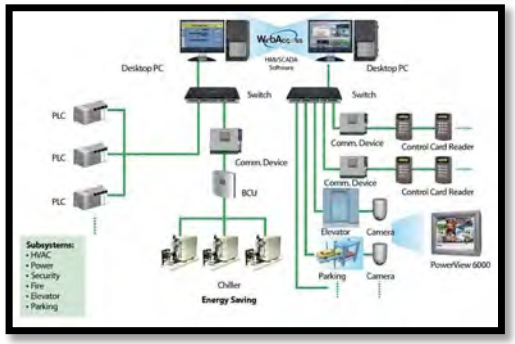
Automation in conjunction with

a building control system

Hybrid: Automation with

manual override

iPad



Variable Tint

Zoning

EC Glass LEED® Certification Credits

EC glass can help earn credits in the following areas:

E&A Credit 1: Optimize energy Performance

IEQ Credit 6: Controllability

IEQ Credit 7: Thermal Comfort

IEQ Credit 8: Daylight & Views

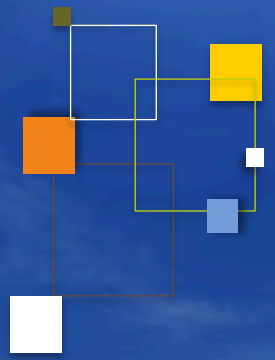
SS Credit 8: Light Pollution

I&DP Credit 1: Innovation In Design

EC Glass Installation

EC glass is easy to specify, integrate, install and use

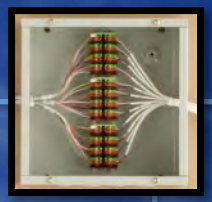
- Proven integration with a wide variety of window, skylight and curtain wall manufacturers
- Architectural Solutions consulting team



Control System Wiring

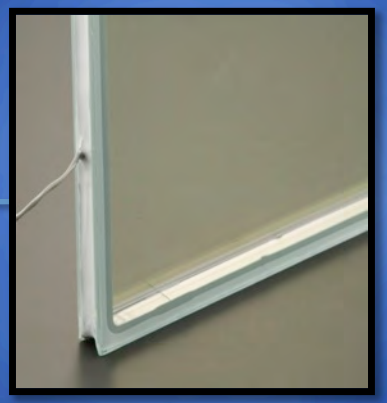
Output Panel

Wall Switch



Terminal Box

Push-In Connector



EC Glass IGU

Interior Light Sensor

Exterior Light Sensor

Electrochromic Product Attributes

- Size

  2012: Up to 40” x 60”
  2013: Up to 60” x 120”

- Non rectangular shapes

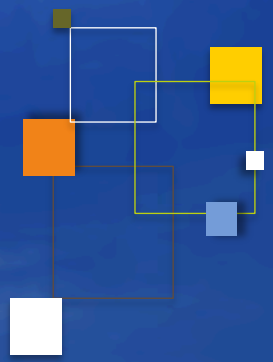
  Parallelograms
  Trapezoids
  Triangle

- Selection of colors

  2012: Transmitted Color Options
  2013: Exterior / Reflected Color Options

- Power consumption

  Up to 2000 ft^2 draws no more than a 60 watt light bulb



Case Studies






Port of Entry
Torrington, WY

Shiley Hall
Portland, OR

Century College
White Bear Lake, MN

Cottage Grove City Hall
Cottage Grove, MN

Club Porticello
Oconomowoc, WI

Landis Hall
Greenwich, CT

Grove City College
Grove City, PA

Ball State
Muncie, IN

St. Johnsbury Athenaeum
St. Johnsbury, VT


Kimmel Center
Philadelphia, PA


Chabot College
Hayward, CA

Colorado Children's Hospital
Denver, CO

NREL
Lakewood, CO

Siemens
Hutchinson, KS

University of Kansas
Lawrence, KS

Department of Energy
Washington, DC

Desert Medical
Palm Springs, CA

UMB Financial Corporation
Scottsdale, AZ

Ajo Border Patrol
Why, AZ

Memphis VA Hospital
Memphis, TN

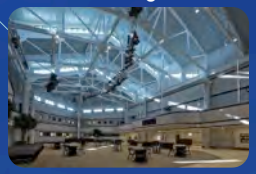
Southface Eco Office
Atlanta, GA


GSA Headquarters
Washington, DC

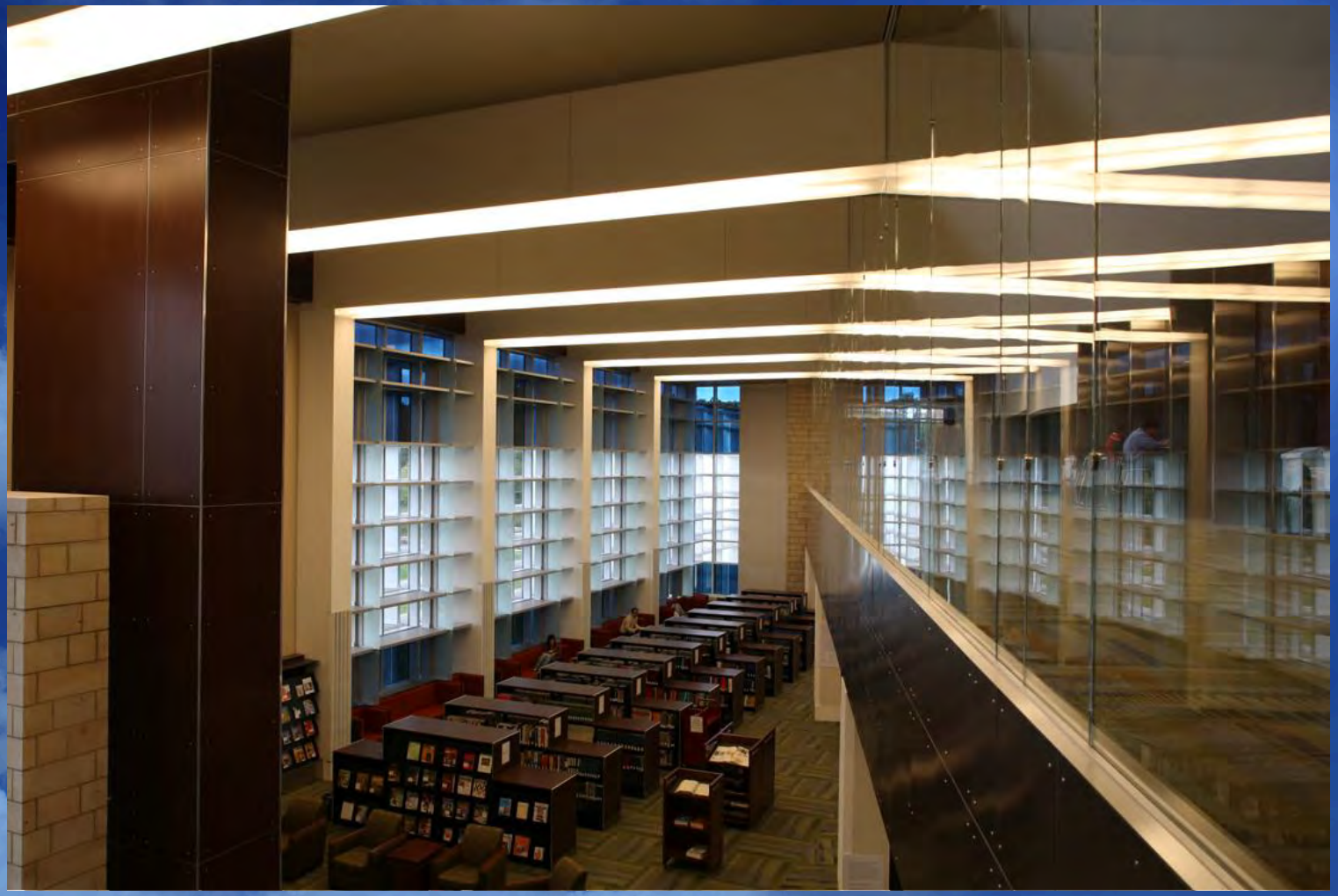

Colorado State University
Fort Collins, CO

Kirksey Architecture
Houston, TX

TD Bank
Miami, FL

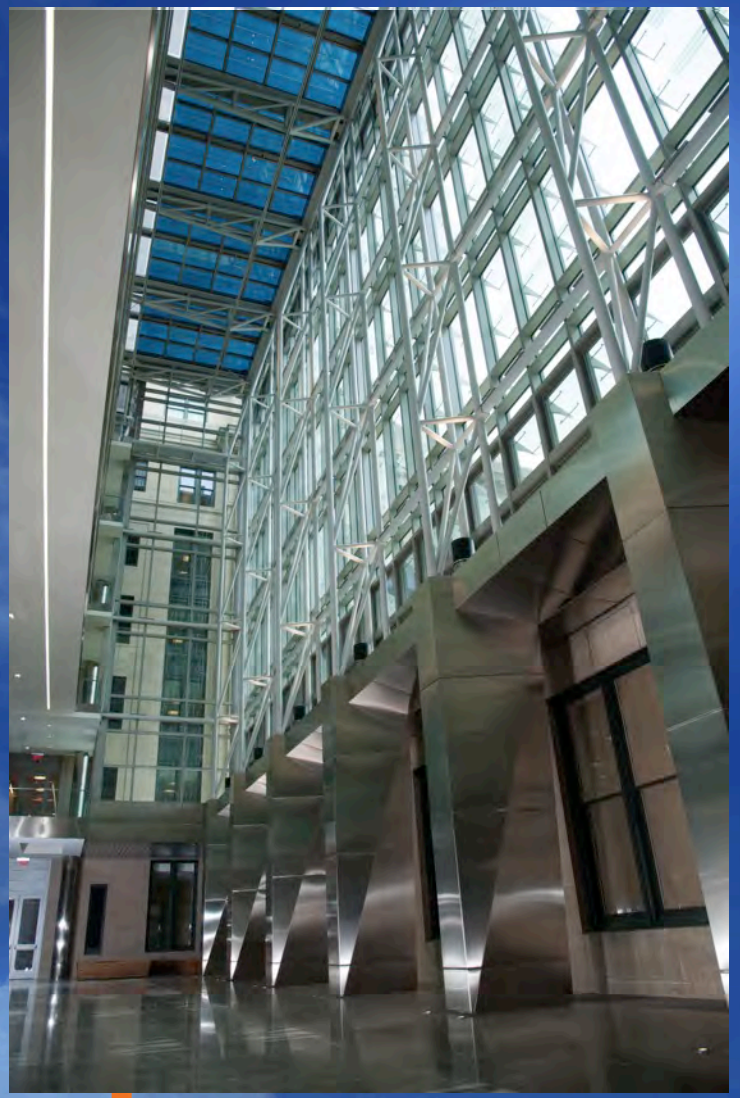

Immanuel Bible Church
Springfield, VA

Century College, White Bear Lake, MN



Chabot College, Hayward, CA

GSA Headquarters, Washington, D.C.



GSA Headquarters, Washington, D.C.

Kimmel Center, Philadelphia, PA

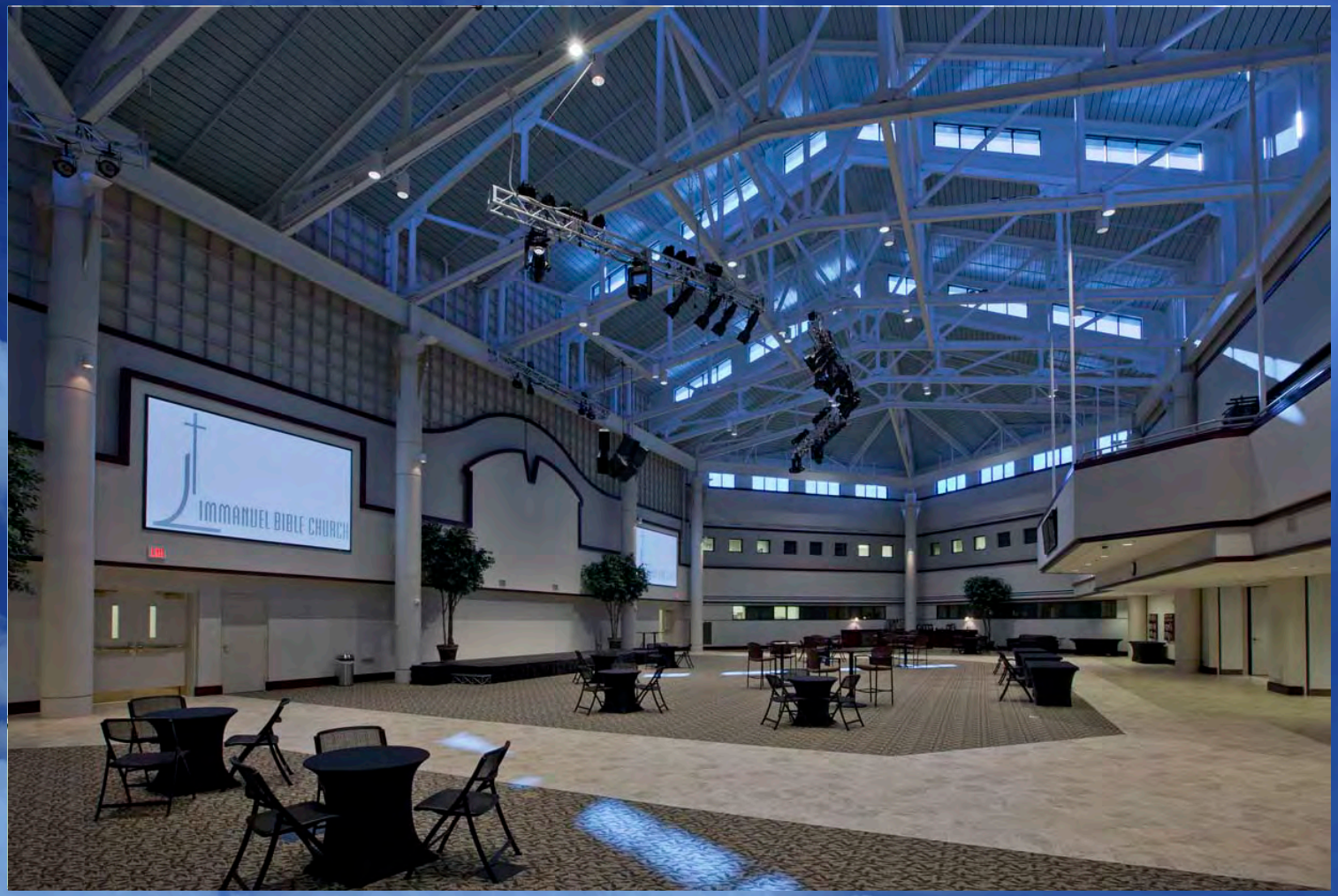
Siemens Wind Turbine Facility, Hutchinson, KS

Siemens Wind Turbine Facility, Hutchinson, KS

Ball State University, Muncie, IN

Club Porticello, Oconomowoc, WI

Immanuel Bible Church, Springfield, VA



Port of Entry, Torrington, WY

St. Johnsbury Athenaeum, St. Johnsbury, VT

Colorado State University, Fort Collins, CO

Grove City College, Grove City, PA

Summary

Dynamic Glass

Glass

Elegant

Glare

Sustainable

Comfortable

Durable

Cost Effective

Where do you sit?

QUESTIONS?

This concludes The American Institute of Architects Continuing Education Systems Program

For more information about electrochromic glazing, contact:

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Pinterest.com/SageGlassUSA