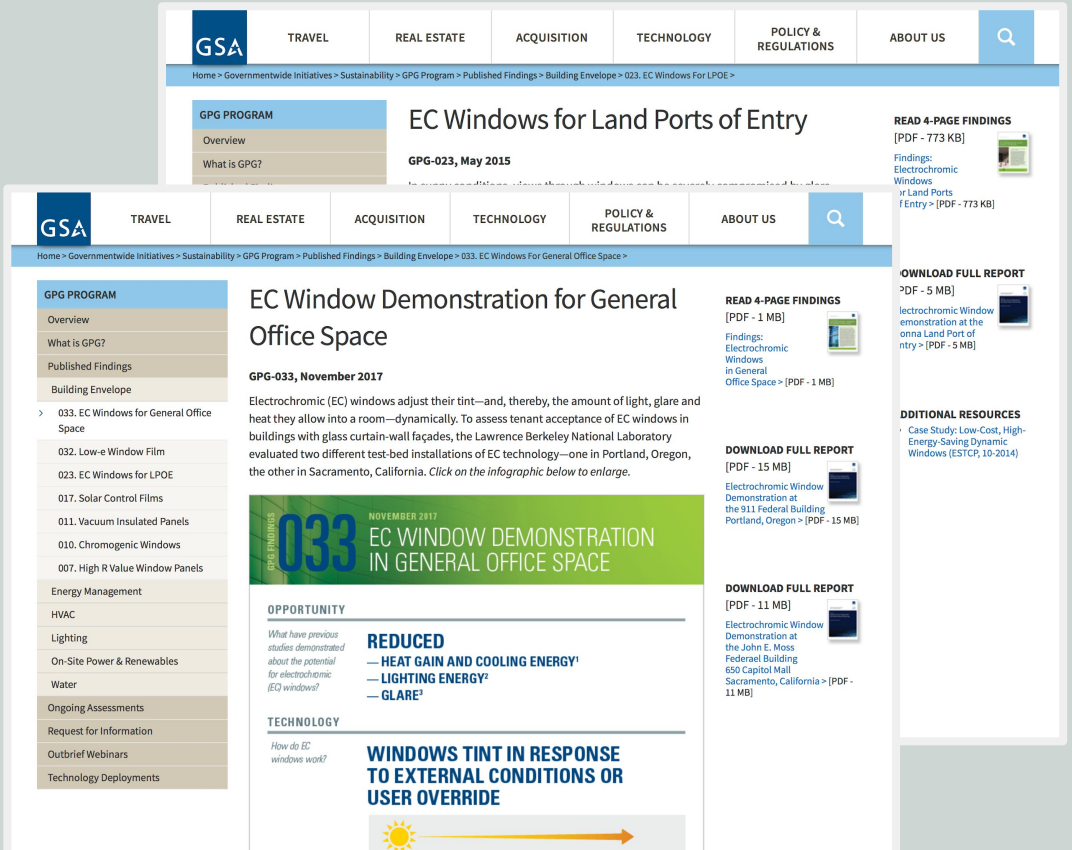
GPG Outbrief 12

Electrochromic (EC) Windows

Emerging Technologies, GPG Program | U.S. General Services Administration | April 19, 2018

GPG-033 EC Window Demonstration for General Office Space
GPG-023 EC Windows for Land Ports of Entry @ gsa.gov

- Infographic
- 4-page Findings
- Full Report
- Additional Resources



Technologies Tested by GPG with Published Results

Building Envelope	HVAC	Lighting	Energy Management	Water	On-Site Renewables
High-R Window Panel Retrofits	Condensing Boilers	Occupant Responsive Lighting	Wireless Sensor Networks	Weather Station for Irrigation Control	Photovoltaics
Thermochromic & Electrochromic Windows	Variable Refrigerant Flow	Integrated Daylighting Systems	Advanced Power Strips	Wireless Soil Moisture Sensors for Irrigation Control	PV Guidance
Vacuum Insulated Panels for Roofing	Variable-Speed Maglev Chiller	Wireless Advanced Lighting Controls	Control Optimization System for Chiller Plants	Non-Chemical Prevention of Hard Water Scale	Photovoltaic-Thermal System
Solar Control Films	Synchronous & Cogged Fan Belts	LED Fixtures with Integrated Controls	Socially Driven HVAC Optimization		Wood-Pellet-Fired Biomass Boiler
Electrochromic (EC) Windows for LPOEs	Multi-staged Indirect Evaporative Cooler	LED Downlight Lamps for CFL Fixtures			Honeycomb Solar Thermal Collector
EC Windows with Dynamic Controls for General Office Space	Variable-speed Direct-drive Screw Chiller	Linear LED Lighting Retrofits			
Low-e Window Films	Wireless Pneumatic Thermostats				
	Smart Ceiling Fans				

Broad Deployment Potential for GSA

Technologies Under Assessment

Building Envelope	HVAC	Lighting	Energy Management	Water	On-Site Renewables
Dual Zone Indoor Shades	Drop-In Smart Switched Reluctance Motor	LED Retrofit Kits with ALCs	Adaptive Control for Chilled Water Plants	Non-Chemical Water Treatment Cooling Towers	
	High- efficiency RTU		Circuit-level Energy Monitoring	Chemical-free Water Treatment	
	Smart Circulator Pump		Predictive HVAC Optimization	Monitoring and Partial Water Softening	
	Intelligent Energy Valves for Hydronic Systems		Wireless Sensor and Analytics		
	Smart Air Scrubbers				

Upcoming 2018 GPG Outbriefs - Thursdays, 12 PM ET

May 10 Honeycomb Solar Thermal Collector

June 7 Variable Refrigerant Flow

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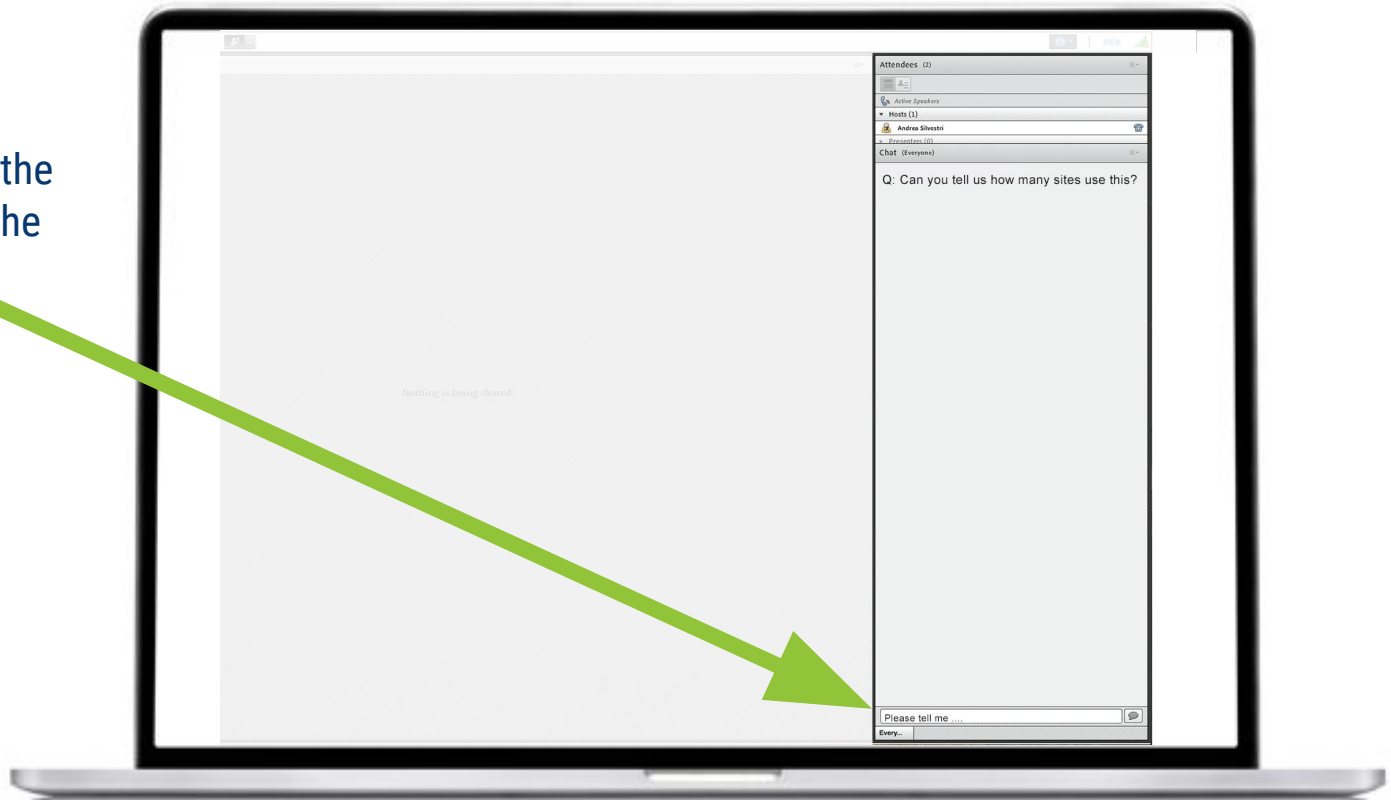
How to Ask Questions

Please chat your questions during the presentation for the Q&A segment



Introduction

Michael Lowell
Project Manager, ET
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720.641.8891

Webinar Agenda

- Introduction (5 minutes)
  Mike Lowell, Project Manager, Emerging Technologies
- EC Windows for Land Ports of Entry (15 minutes)
  Luís Fernandes, Lawrence Berkeley National Laboratory
- On-the-ground Feedback (15 minutes)
  Amy Mendoza, Donna Land Port of Entry
- EC Windows for General Office Space (20 minutes)
  Eleanor Lee, Lawrence Berkeley National Laboratory
- On-the-ground Feedback (15 minutes)
  Marty Novini, GSA Region 10
  Jim Carter, GSA Region 10
- Q & A (20 minutes)

Emerging Technologies' two programs — GSA Proving Ground (GPG) and Pilot to Portfolio (P2P) — enable GSA to make sound investment decisions in next generation building technologies based on their real world performance

Measurement & Verification—Donna, Texas

Luís Fernandes, PhD
Building Technology and Urban Systems
Lawrence Berkeley National Laboratory

GPG-023

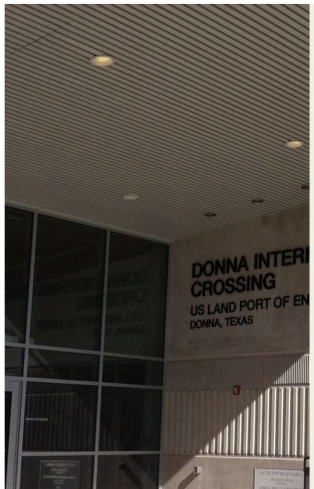
EC Windows at Land Ports of Entry

General Services Administration
Public Buildings Service

GSA

GPG-023 | MAY 2015

EC WINDOWS AT LAND PORTS OF ENTRY



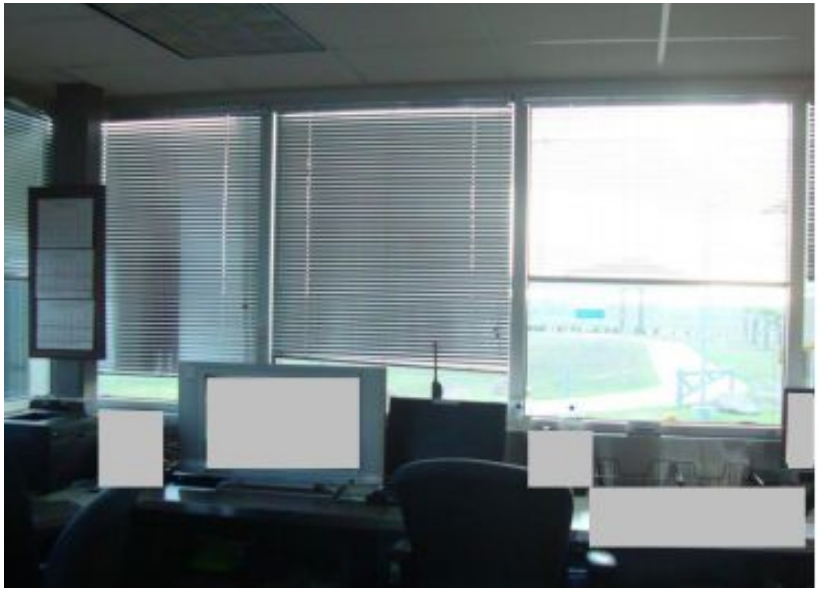
Electrochromic Windows Reduce Glare While Preserving Line of Sight

At Land Ports of Entry (LPOE), military installations and other facilities where occupants monitor outdoor activities, visibility through windows is critical. Most facilities use surveillance cameras to monitor their surroundings, but officers stress the unique importance of direct "line of sight," an uninterrupted visual path between the observer and the observed. In sunny conditions, direct visual contact can be severely compromised by window glare. But conventional solutions to control glare, like tinted films and window coverings, can obstruct views and inhibit visual security. Electrochromic (EC) windows preserve line of sight and beneficial daylight while controlling glare. With this technology, windows tint from clear to dark and back again, either automatically or in response to a manual override. To assess EC's glare-modulating performance, GSA's GPG program commissioned Lawrence Berkeley National Laboratory (LBNL) to conduct a pilot study at the Donna LPOE at the Texas border with Mexico. Researchers found a significant

Potential Benefit of EC Windows for LPOEs

Provide Direct Line of Sight

An uninterrupted visual path between the observer and the area under surveillance



Venetian blinds blocking the view on a sunny afternoon, prior to the installation of electrochromic windows

How EC Windows Work

Windows Transition from Clear to Dark Without the Need for Window Blinds

TRANSITION FROM CLEAR TO DARK

USING PHOTOSENSOR READINGS AND SUN PATH CALCULATIONS

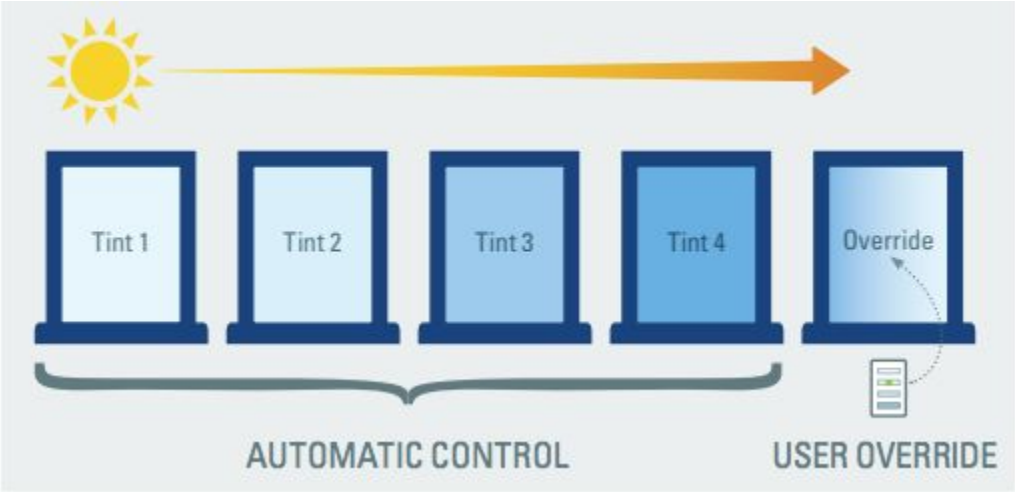
GLARE

REDUCTION

BELOW PERCEPTIBLE
GLARE THRESHOLD

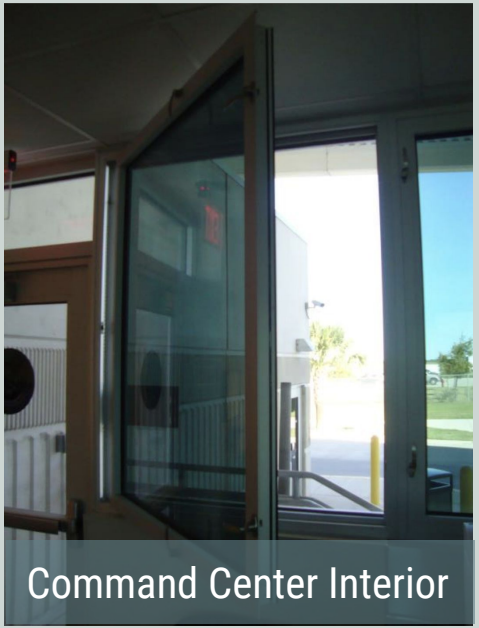
Measurement & Verification

Windows Tint in Response to External Conditions or to User Override



Measurement & Verification

Researchers Monitored Performance at Donna, Texas Land Port of Entry


Command Center Interior


Vehicle Booth Exterior

Switch

Monitored Before and After Conditions

Primary evaluation was occupant surveys. To aid in the understanding of survey results, we also conducted physical measurements.

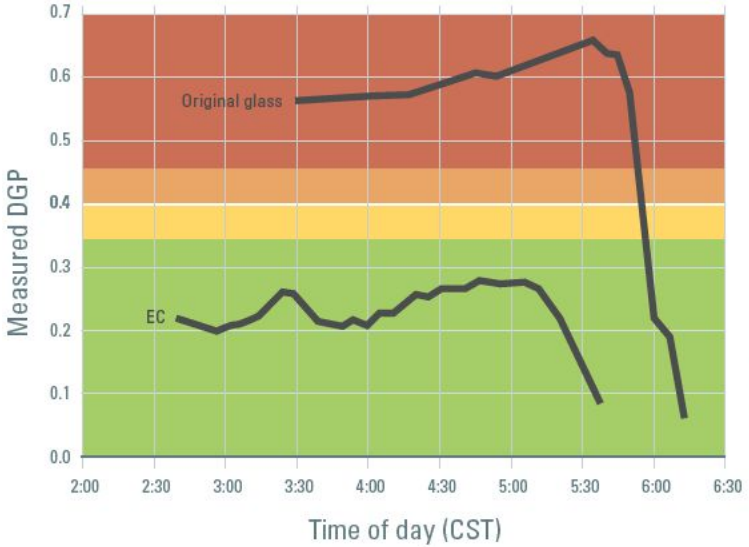
- Glare measurements
- Glass surface temperature measurements
- Nighttime visibility
- How frequently occupants used the manual switches

100% User Preference

Booth With EC Has Much Lower Glare Throughout a Sunny Afternoon

Nighttime visibility is reduced with increased interior reflection.

Overhead canopy over the entire area shaded the EC windows from direct sunlight.



DGP	Qualitative Interpretation
> 0.45	Intolerable glare
0.40 to 0.45	Disturbing glare
0.35 to 0.40	Perceptible glare
< 0.35	Imperceptible glare

DGP is a metric for visual comfort, with values from 0 to 1, representing the probability that a person would experience disturbing glare in a particular situation.

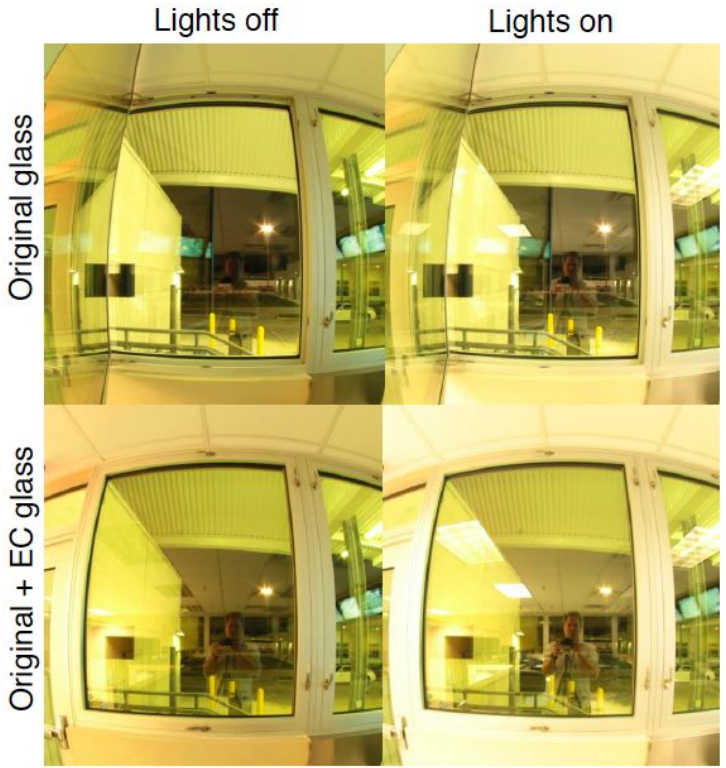
100%
USER PREFERENCE
OVER CONVENTIONAL WINDOWS

Nighttime Visibility Reduced

Window Coatings Increase Reflections on the Interior Surface of Windows at Night

When the area outside is darker than the rooms inside, window reflections become more pronounced.

Measurements showed a reduction in visibility though occupants did not comment



Careful Planning Required

Bullet-Blast- and Wind-Load Resistance

- Warranties can be voided with changes.
- Retrofitting on top of existing window means dirt, heat and moisture can accumulate between EC and original IGU. At Donna, EC was installed in operable window frames to guard against such problems.

Expensive but Alternatives Lack Functionality/Flexibility

Limited Cost-Effectiveness for Some Applications—Minimum of $45/ft^2

Permanently applied screens or films

- Can't respond to variety of glare and light levels.

Operable screens/films

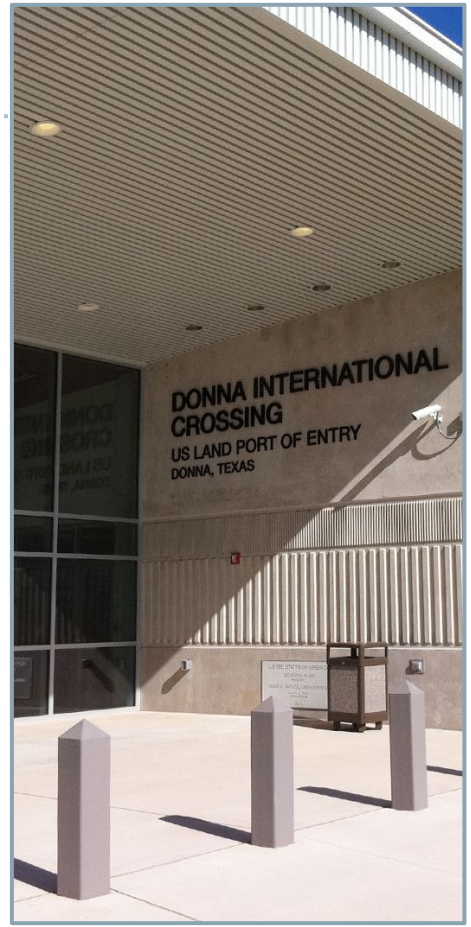
- Require frequent adjustments.

Automated shades

- Movement could be distracting.

Deployment

Consider for Land Ports of Entry and other facilities where window glare compromises mission-critical outdoor visibility



Donna Land Port of Entry Feedback

Amy Mendoza
Building Management Specialist
Border Service Center
Progreso/Donna Port of Entry

Donna Land Port of Entry Feedback

- No issues; received a lot of positive feedback
- Continued satisfaction 4-years later
- Officers use them a lot, particularly mornings
- Cleaning requirements have not been a problem
- Would like to install EC on the other inspection booths, but funding is limited

Measurement & Verification–Sacramento and Portland

Eleanor Lee, Staff Scientist
Building Technology and Urban Systems
Lawrence Berkeley National Laboratory

GPG-033

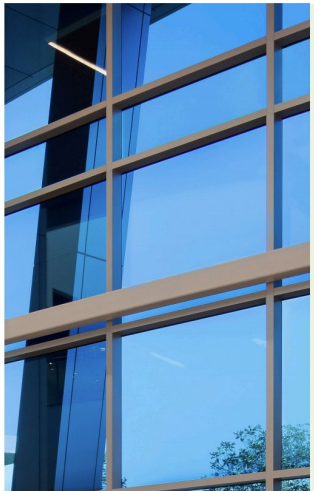
EC Windows in General Office Space

General Services Administration
Public Buildings Service

GSA

GPG-033 | NOVEMBER 2017

ELECTROCHROMIC WINDOWS IN GENERAL OFFICE SPACE



Occupants Prefer EC Over Legacy Windows

Electrochromic (EC) windows are part of a new class of technologies that together comprise "dynamic façades." Able to respond to their environment by changing behavior, dynamic façades are among the most significant recent developments in commercial building technology, and EC windows, with their ability to manage heat and glare actively, promise to play an important role in their evolution. To assess tenant acceptance of EC windows in buildings with glass curtain-wall façades, the Lawrence Berkeley National Laboratory (LBNL) evaluated two different test-bed installations of EC technology—one in Portland, Oregon, the other in Sacramento, California. Findings demonstrated that the majority of occupants preferred EC windows over the existing windows. On a more granular level, however, satisfaction was mixed, and it was challenging for the technology to satisfy occupants' aesthetic and glare requirements, while implementing control strategies that deliver HVAC and lighting savings. In both test bed locations, this conflict had the effect of reducing return on investment and, in the end, this evaluation concluded that broad deployment of EC windows across GSA office space would not be cost-effective based on energy savings alone. There are, however, circumstances under which EC windows would be beneficial. For instance, an earlier GSA Proving Ground (GPG) study found that EC windows are an effective solution for facilities where window

Measurement & Verification

Researchers Monitored Occupant Satisfaction at Two Federal Locations

John E. Moss Federal Building, Sacramento, CA and the 911 Federal Building, Portland OR

South-facing windows with high window-to-wall ratios

Technology for test-bed measurement and verification provided by SageGlass and View Glass

Reference and Test Case Windows

Sacramento

Original windows (approx): Tvis=0.61, SHGC=0.45
EC windows: Tvis=0.60-0.01, SHGC=0.41-0.09

VISIBLE TRANSMITTANCE (TVIS)
Measurements

SACRAMENTO

ORIGINAL WINDOWS
as estimated by LBNL

Tvis	**0.61**

EC WINDOWS
as specified by GSA

Tvis - 1. Clear*	**0.60**
Tvis - 2. Light Tint	**0.18**
Tvis - 3. Medium Tint	**0.06**
Tvis - 4. Full Tint	**0.01**

Portland

Original window (approx): Tvis=0.15, SHGC=0.16
EC windows: Tvis=0.36-0.02, SHGC=0.43-0.09

VISIBLE TRANSMITTANCE (TVIS)
Measurements

PORTLAND

ORIGINAL WINDOWS
as estimated by LBNL

Tvis	**0.15**

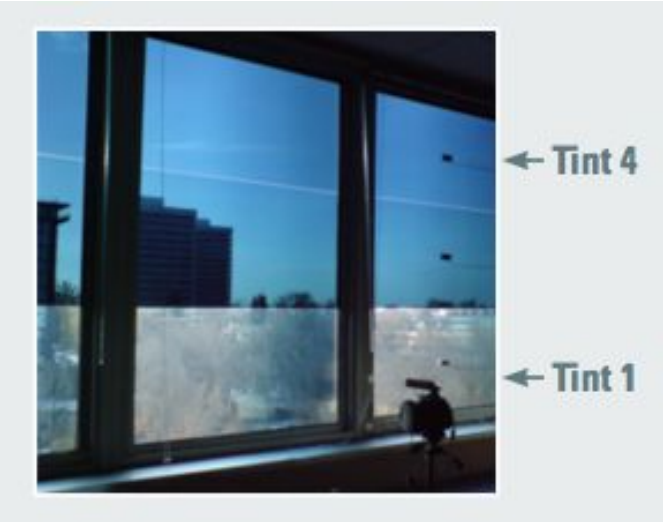
EC WINDOWS
as specified by GSA

Tvis - 1. Clear*	**0.36**
Tvis - 2. Light Tint	**0.25**
Tvis - 3. Medium Tint	**0.13**
Tvis - 4. Full Tint	**0.02**

Single vs Multi-zone Tinting

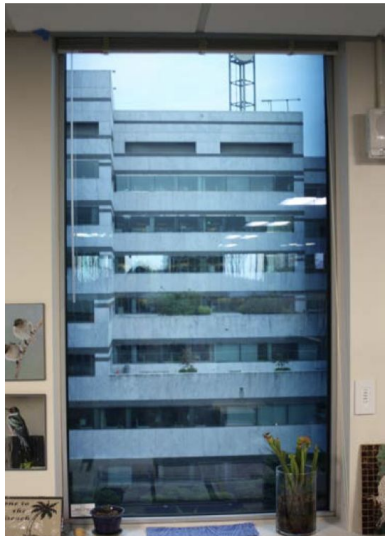
Sacramento—Multiple Tint Zones

In glare mode, the top and middle sub-panes are at full tint, the bottom pane is in daylight mode.



Portland—Single Tint Zone

Single tint zone was somewhat easier to control.



Window Tint Influences HVAC Savings

EC SHGC Switching Range Lower Than Reference Window Will Reduce HVAC Loads

Darkest tint levels not always acceptable to occupants

Sacramento—Tested at Advanced Windows Testbed, Berkeley CA

Daily HVAC load **decreased 29-65%**

Peak load **decreased 25-58%**

SHGC=0.45 (ref) versus 0.15-0.09 (Tint 2-4)

Portland

Daily HVAC **increased 2%**

Darkest automatic tint levels disabled in winter

SHGC=0.16 (ref) versus 0.43-0.16 (Tint 1-3)

Room C	Room B	Room A
EC glass	EC glass	Reference glass

Blind Use and Window Tint Influence Lighting Energy Savings

Savings Influenced by Occupant Preferences for Daylight

Study was inconclusive whether lighting savings would be realized; base case impacts results

Sacramento—sunny climate

Daily lighting load **increased 62%**

Tvis=0.61 (ref) versus 0.18-0.01 (Tint 2-4) and most blinds were lowered with ECs

Portland—cloudy climate

Daily lighting load **decreased 36%**

Tvis=0.15 (ref) versus 0.36-0.13 (Tint 1-3); 40% more blinds were left raised with ECs

Limited Cost-Effectiveness in General Office Applications

Incremental Payback Estimated at 13 Years

- Installed cost of EC insulating glass unit: $61/ft^2-window area
  Installed cost of dual-pane low-e insulating glass unit: $24/ft^2
  Mature market cost as estimated by the manufacturer
- The incremental difference between installing EC windows and spectrally selective low-e windows was estimated at $37/ft^2 with a payback of **13 years**
- Payback estimated at **29 years** as a retrofit replacing existing glazing that is still functional
- Assumes GSA national average utility rate of $0.11/kWh and use of blinds for both the EC and low-e windows

Occupants More Satisfied with EC Windows

Sacramento

63% of occupants preferred EC windows over the existing windows

Portland

85% of occupants in private offices

92% in open offices preferred EC windows over the existing windows which had a dark tint to begin with

Control Algorithms Need Fine Tuning

EC Window Technologies Operated as Intended

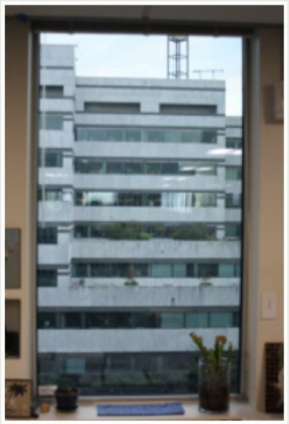
- Automatic Controls Were Not Yet Turnkey

Speed of Response

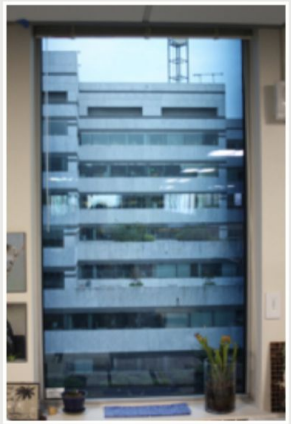
Switching Speed is Influenced by Window Size and Temperature

In Portland, on April 10, 2016, windows took 28 minutes to fully tint on a cool, overcast day.

Occupants were neutral on whether the speed was satisfactory (response of 4-6; 5=neutral on scale of 1-9)

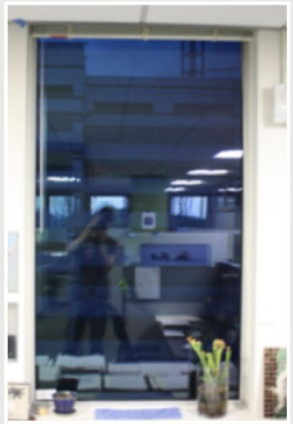


Tint 1 - 6:25 pm



Tint 2 - 6:31 pm

Tint 3 - 6:43 pm



Tint 4 - 6:53 pm

Lessons Learned

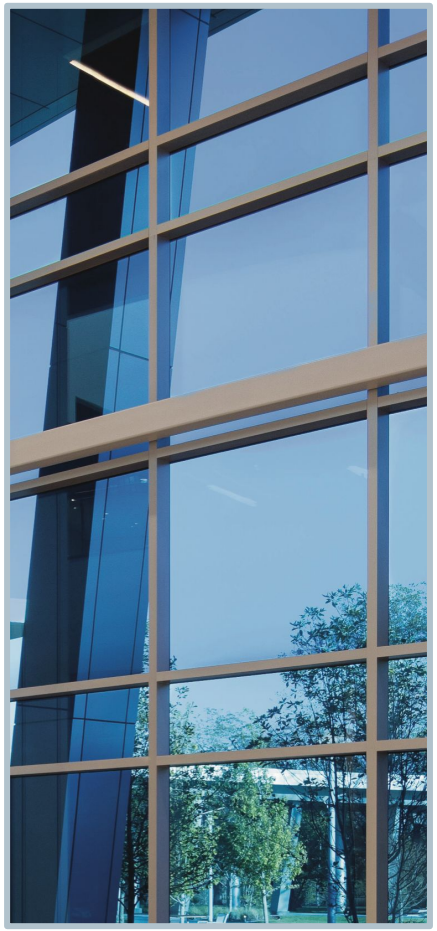
- Select clear windows to facilitate a broad switching range
- Configure installations into zones
- Test before you install
- Educate occupants, manage expectations
- Proper commissioning takes time

The U.S. General Services Administration's Green Proving Ground program is proud to evaluate state-of-the-art electrochromic windows in your workspace. These windows will dynamically tint in response to outdoor conditions to protect you from glare, while preserving your views of beautiful Portland. We hope that your new windows will improve your thermal and visual comfort while saving energy.

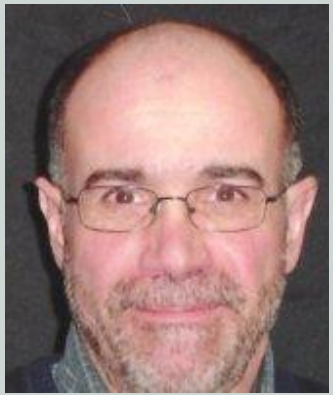
We want to hear your feedback!
Send questions and concerns about your windows to r10servicecalls@gsa.gov.

Deployment Recommendations

- New construction/major renovation
- Existing facilities with the following attributes:
  - Where outside views are critical
  - Seasonal thermal comfort challenges
  - Atriums and skylights
  - Public spaces where blinds are impractical
  - Need to reduce peak cooling load
  - Radiant cooling



GSA Feedback, R10



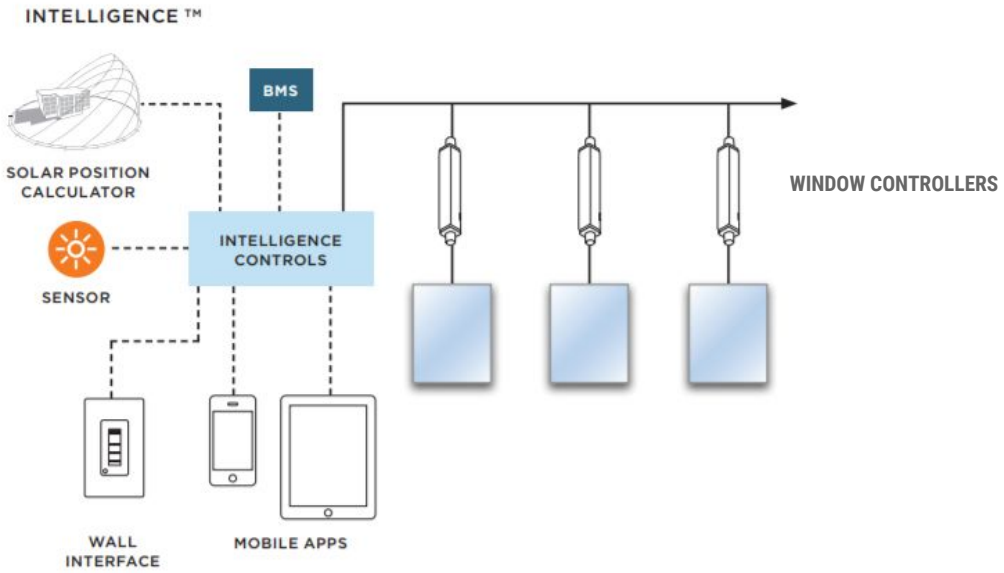
Marty Novini
Energy Program Manager
Northwest Arctic Region 10

911 Portland—Feedback

- Building needed EC because of zoning issues—cheaper, easier solution.
- EC Windows have done the job. Reduced heat gain without sacrificing views.
- Tints 1, 2 and 3 are not that different from the original tint. Tint 4 is considerably darker and the only one that really reduces the load, but it's too dark for the tenants.
- Project was great for the tenants, because it gave them control.
- The impact on energy savings wasn't as large as we thought, because we don't have a huge cooling demand in the northwest.

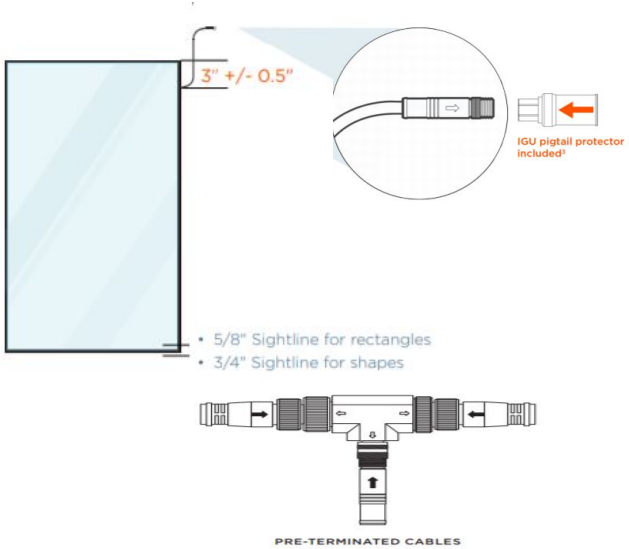
911 Portland—Controllers

- Make sure the window controllers are installed in an accessible location. We installed controllers 12' from windows, mostly hallways, for easy access by maintenance.



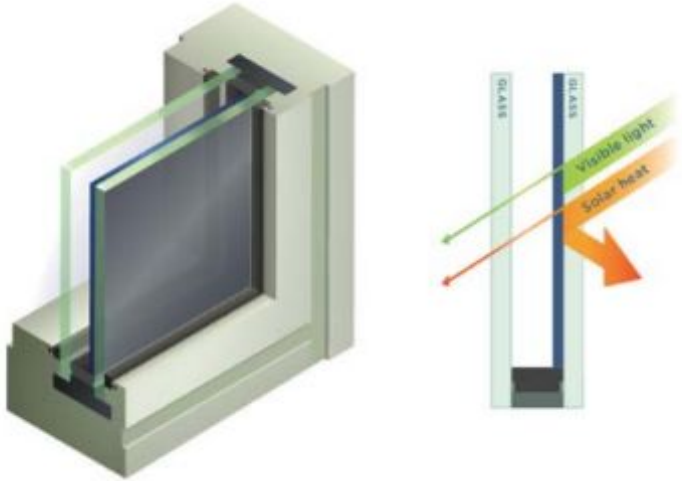
911 Portland—Installation

- For open offices, make sure the window zoning matches floor layout. We installed one window controller per window, considering future space changes.
- Specify cable length to the manufacturer.



911 Portland—Installation

- Consider blast protection as part of installation. The thickness of the blast film can impact the overall thickness of the EC glass assembly which cannot be greater than the existing glass assembly.
- A local glazier helped us with installation details.



Additional Applications

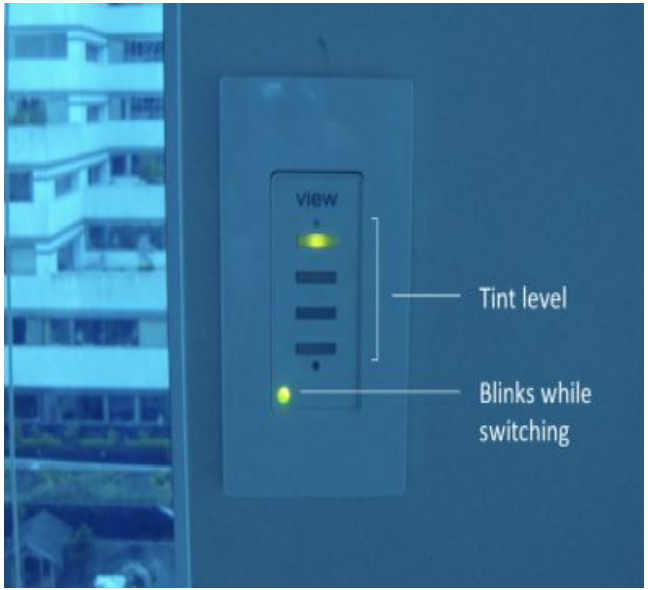
- EC windows can solve solar glare and solar heat gain problems, without sacrificing views.
- Other potential applications within region 10:
  - In Seattle, high-performing building that has seasonal issues with skylights—solar load and glare in summer but fine in the winter.
  - In Alaska, in summer, with extended daily solar exposure, sun heats up the space, but in winter sun is desirable.
  - In Boise, building with extensive solar gain on south and southwest facing zones.

GSA Feedback, R10

Jim Carter
911 Federal Building
Operations Manager

911 Portland—Controls

- Modified controls seasonally:
  - Summertime set to tint 4 on weekends.
  - Wintertime set to tint 1 all week.
- Could not change/abort a transition once a level was selected.
  - Challenging in Portland where sky conditions change rapidly. This remains biggest tenant complaint. *Newer EC windows do not have this problem.*



911 Portland—Tenant Satisfaction

- **Blind use has decreased as tenants have become more comfortable with windows.**
- A few tenants—out of a few hundred—are light sensitive: use blinds and darken the windows to the darkest setting.
- In conference rooms, it would be good if windows could go totally opaque, blinds are still needed during video projection.

911 Portland—Operations

- Sensors for multiple floors would be beneficial.
- Connectivity is important, and because it's separate from GSA network it's possible.
- Mobile application would be great to offer to tenants but IT security limits this.
- View continues to support, monitor and be responsive to requests.

911 Portland—Lessons Learned

- Order 1 or 2 extra windows to have on hand.
- Federal buildings require blast film, include blast film with manufacturing.
- Have found EC windows to be a good technology and would use them again.
  - Provide a continuous view to the outside
  - Help with solar heat gain
  - Add to the building envelope

Q & A

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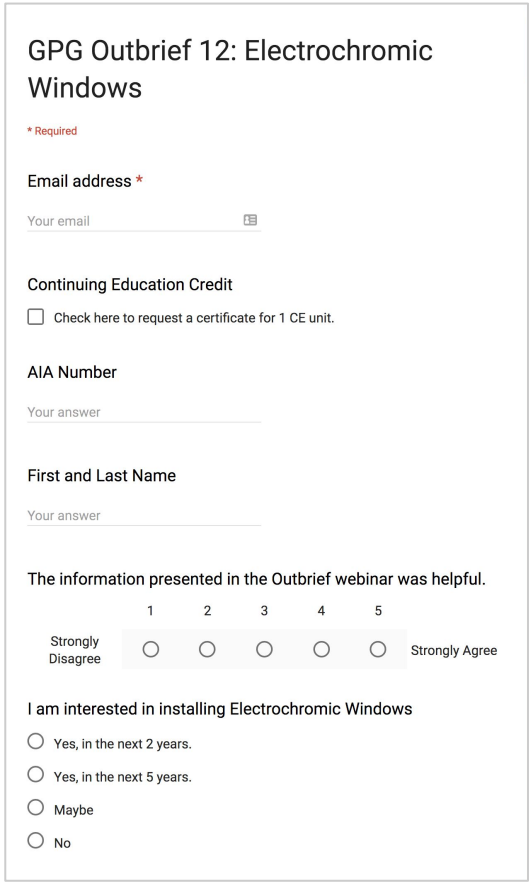

GPG Outbrief 12: Electrochromic Windows

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Check here to request a certificate for 1 CE unit.

AIA Number

Your answer

First and Last Name

Your answer

The information presented in the Outbrief webinar was helpful.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

I am interested in installing Electrochromic Windows

- ○ Yes, in the next 2 years.
- ○ Yes, in the next 5 years.
- ○ Maybe
- ○ No

Thank you

For more information: gsa.gov/GPG

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Kevin Powell, Program Manager kevin.powell@gsa.gov 510.423.3384