Building Smart Airports:
A Case Study Look at Smart Glass Impacts on Passenger Experience, Revenue, Operations and Sustainability

Webinar summary

Today’s traveling public demands technology and service standards in the airport terminal that rival those outside the travel experience. Airports work to identify solutions that improve the passenger experience, while reducing operational expenses and improving revenue streams. Smart glass is one solution. The high-tech glass system reduces glare and unwanted heat within a terminal, provides a comfortable environment for passengers, and reduces an airport’s carbon footprint and operations. Today we look at two airport case studies: SFO and DFW.
Learning Objectives

• Understand how smart glass enhances sustainability initiatives
• Explore the benefits to airport operations with smart glass
• Learn how smart glass can positively impact passenger experience
• Learn how smart glass increases non-aeronautical revenue

Speaker Bios

Brandon Tinianov

Dr. Tinianov’s 25-year career has been dedicated to product innovation in building technology and real estate. He currently serves as View’s VP of Industry Strategy where he leads their industry research. His work spans current trends in commercial real estate, workplace strategy, and the impact of the built environment on the health and wellness of today’s workforce. Prior to joining View, Brandon was the Chief Technology Officer at Serious Energy and prior to that, a senior researcher at the Johns Manville Corporation.

Brandon is the Chair of the Advisory Council of the US Green Building Council and a the Board of Directors Treasurer. He has a PhD in Engineering Systems, is a registered PE and a LEED AP.

Kirsten Ritchie

Kirsten Ritchie, a Principal and Director of Sustainable Design at Gensler, has over 30 years of experience in the world of green building and sustainable materials. She is a passionate advocate for innovative, science based approaches to assess performance. She is currently leading a number of projects focused on delivering exceptional experience and low carbon impact - both embodied and operational carbon.

In her role as Director of Sustainable Design, Ms. Ritchie works with a broad range of clients including San Francisco International Airport, Facebook, and Google. She is a past USGBC Board and MR-TAG member and currently serves on the advisory board of the Ecological Building Network and the Materials Carbon Action Network. Ms. Ritchie is a registered Professional Engineer and LEED O+M AP.
Agenda

• Introduction of View & Gensler
• SFO Case Study
• DFW Case Study
• Questions

View is shaping the future of modern buildings

Select Investors:
View Smart Glass intelligently changes tint

<table>
<thead>
<tr>
<th>Tint 1</th>
<th>Tint 2</th>
<th>Tint 3</th>
<th>Tint 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visible Light Transmission</td>
<td>58%</td>
<td>40%*</td>
<td>6%*</td>
</tr>
<tr>
<td>Solar Heat Gain Coeff.</td>
<td>0.42</td>
<td>0.29</td>
<td>0.12</td>
</tr>
<tr>
<td>UV Transmission</td>
<td>4%</td>
<td>2%</td>
<td>1%</td>
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</table>

* Tint 4 transmission can be decreased to 0.5%; transmission in Tint 2 and 3 can also be adjusted upon request.

Current Aviation Projects

- Alaska Airlines Lounge Seattle
- Delta Sky Club Seattle
- Logan International Airport
- Charlotte Douglas Airport
- Meacham International Airport
- San Francisco International Airport
- DFW International Airport
- LaGuardia Delta Head House
- Spokane International Airport
- Bozeman Yellowstone International Airport
- Memphis International Airport

All Terminals in progress
About Gensler

For more than 50 years, Gensler has been a leading global architecture, interiors, planning, and strategic consulting firm that partners with public and private sector clients to achieve measurable results through design.

Gensler has roots centered in three decades of aviation facilities experience, planning and architectural design. We know that each square foot in an airport represents a significant investment and must justify itself in performance and productivity.

Gensler provides specialized services that enhance the passenger experience through improved efficiency, level of service and integration at the airport. Cutting through, making journeys through an airport an authentic experience positively affects passengers' efficiency and safety, enhances revenue development and creates an airport that is visually representative of the local culture.

The airport experience needs to communicate the city's vibrance and energy to the passengers as well as the sophistication and reliability that constitutes that city's brand.

List of Selected Aviation Projects

<table>
<thead>
<tr>
<th>Project</th>
<th>Location</th>
<th>Completed</th>
<th>Size (sf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>San Francisco International Airport</td>
<td>San Francisco, CA</td>
<td>Ongoing</td>
<td>800,000</td>
</tr>
<tr>
<td>American Airlines Terminal 3</td>
<td>Los Angeles, CA</td>
<td>1981</td>
<td>1,290,000</td>
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<tr>
<td>LAX, McNamara Satellite Concourse</td>
<td>Los Angeles, CA</td>
<td>2019</td>
<td>309,071</td>
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<tr>
<td>Delta Sky Way at LAX</td>
<td>Los Angeles, CA</td>
<td>2010</td>
<td>687,179</td>
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<tr>
<td>San Diego International Airport</td>
<td>San Diego, CA</td>
<td>2019</td>
<td>225,625</td>
</tr>
<tr>
<td>Incheon International Airport</td>
<td>Incheon, South Korea</td>
<td>2018</td>
<td>4,144,336</td>
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<tr>
<td>San Francisco International Airport</td>
<td>San Francisco, CA</td>
<td>2012</td>
<td>241,297</td>
</tr>
<tr>
<td>Chennai International Airport</td>
<td>Chennai, India</td>
<td>2012</td>
<td>1,276,000</td>
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<td>San Francisco International Airport</td>
<td>San Francisco, CA</td>
<td>2012</td>
<td>460,000</td>
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<td>Tulsa International Airport</td>
<td>Tulsa, OK, USA</td>
<td>2012</td>
<td>100,000</td>
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<td>Jackson Hole Wyoming Airport</td>
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<td>2011</td>
<td>108,000</td>
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<td>Los Angeles International Airport</td>
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<td>2011</td>
<td>4,430,000</td>
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<td>Hartsfield-Jackson Atlanta Int’l Airport</td>
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<td>2011</td>
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<td>John Wayne Airport</td>
<td>Orange County, CA, USA</td>
<td>2011</td>
<td>500,000</td>
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<td>San Jose International Airport</td>
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<td>735,000</td>
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<td>Portland International Airport</td>
<td>Portland, OR, USA</td>
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<td>440,000</td>
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<td>Hudson International Airport</td>
<td>Hudson, China</td>
<td>2010</td>
<td>2,000,000</td>
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<td>New Lisbon International Airport</td>
<td>Lisbon, Portugal</td>
<td>2009</td>
<td>2,500,000</td>
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<td>JFK Terminal 5 (JFK International Airport)</td>
<td>Jamaica, NY, USA</td>
<td>2008</td>
<td>600,000</td>
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<td>Detroit Metropolitan Wayne County Airport</td>
<td>Detroit, MI, USA</td>
<td>2008</td>
<td>800,000</td>
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<td>Austin Bergstrom International Airport</td>
<td>Austin, TX, USA</td>
<td>2008</td>
<td>650,000</td>
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<td>Palm Springs Regional Airport</td>
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<td>2006</td>
<td>225,000</td>
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<tr>
<td>London- City Airport</td>
<td>London, United Kingdom</td>
<td>2006</td>
<td>250,000</td>
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<td>Salt Lake City International Airport</td>
<td>Salt Lake City, UT, USA</td>
<td>2005</td>
<td>800,000</td>
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<tr>
<td>Long Beach Airport</td>
<td>Long Beach, CA, USA</td>
<td>2005</td>
<td>60,000</td>
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<tr>
<td>Singapore Changi International Airport</td>
<td>Changi, Singapore</td>
<td>2003</td>
<td>1,050,000</td>
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<tr>
<td>Caspian Chirv International Airport</td>
<td>Chirv, Chirv, Iran</td>
<td>2003</td>
<td>130,000</td>
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<td>Cairo, Cairo International Airport</td>
<td>Cairo, Egypt</td>
<td>2003</td>
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<td>Salt River Phoenix Global Airport</td>
<td>Tempe, AZ, USA</td>
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<td>240,000</td>
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<tr>
<td>San Diego International Airport</td>
<td>San Diego, CA, USA</td>
<td>1996</td>
<td>365,000</td>
</tr>
</tbody>
</table>
Creating Dynamic Communities...

That is the foundation of our approach to elevating the passenger experience.

Gender has planned and designed airports and transit facilities at every scale, worldwide. As a full-service global design firm, we bring exceptional talent and expertise to every airport project we undertake.

We are proud to claim the #1 spot in transportation design in Interior Design Magazine’s Top 100 Design Giants.

Creating Sustainable Opportunities...

Airport projects are legacy projects. What we build today will be carried down for generations to come, and that is why it is of paramount importance that they be sustainable, economical and lasting.

Incheon International Airport T2 is an excellent example of sustainable terminal design done right. Sustainability strategies were integrated throughout the project as new building systems and technologies were designed for optimal efficiency for minimum energy and water consumption. Park-like gardens within the terminal showcase native plants and vegetation.
Impact by Design
SMART AIRPORTS | SMART GLASS

Harvey Milk Terminal
Terminal 1

BHAG’s

SFO will reach zero net energy, zero net carbon emissions, and zero waste production.

SFO will be a model of sustainability and proactively seek to engage, educate and influence others, including its employees, tenants, airlines, passengers and neighbors.
The SFO T1C/N renovation project, encompassing over 770,000 sf is designed to enable the terminal to handle a **70% increase in passengers** (from the current 10 million to a planned 17 million), while **improving** employee and passenger satisfaction and delight, **increasing revenues** from retail, food and beverage operations, and **lowering energy use and carbon emissions** more than **75%** from current operations.

**Rigorous Analysis**

**SFO OPERATIONAL DATA COLLECTION AND ANALYSIS**
Both quantitative and qualitative data were collected and analyzed in order to understand and identify the best energy use reduction opportunities for the project.

**SIMULATION AND MODELING**
Numerous simulation and modeling tools were used to understand the energy, carbon, and comfort performance of design and technology solutions. Some of the tools used include:
1. Revit
2. Energy Pro
3. LightStyr
4. Revit Energy Modeling
5. Autodesk 3ds Max
6. Photoshop
7. DUI

**LIFE CYCLE COST ANALYSIS**
Integrating energy modeling results with capital costs, utility costs and other operational factors, a life cycle cost analysis was completed for each technology study. The LCCA output provides the following environmental and financial performance results:
1. Annual Energy Reduction (kBtu/YR)
2. EUI Reduction (kBtu/ft²/YR)
3. Annual Cost Savings (K)
4. CapEx Cost - CO2 and D&M ($)
5. Simple Payback (YR)
6. Return on Investment (NI)
7. Net Present Value ($)
8. Savings to Investment Ratio (%)
9. EUI CapEx Cost (K$/SF, Reduced)
10. Annual Carbon Reduction (kBtu/YR)
11. Annual Avoided Cost of Carbon ($)

**TECHNOLOGY SNAPSHOT**
For each technology evaluated, a technology snapshot was prepared providing a summary of the technology, key considerations, applicability in the T1C/N project, key environmental and financial metrics from the LCCA and a summary of the following Environmental and Operations Considerations:
1. Passenger and Employee Experience
2. Accessibility
3. Future Flexibility
4. Innovation Acceleration
5. Operational Considerations
6. Schedule Implications
7. Other Decision Factors

**Contractor**
- Hensel Phelps
- Design Team
- Gensler/Kuth Ranieri JV
- Engineer
- Meyers+
A Little Glare Problem

Scenario:
Southwest orientation, estimated to be ‘worst case’, eg maximum glare probability over the course of the year 3037 Annual Daylight Hours, 2279 hours of which are estimated to experience glare issues if only baseline is used.

- Intolerable Glare >45%
- Disturbing Glare >40%
- Perceptible Glare >35%
- Imperceptible Glare <35%

Technology Snapshot: Dynamic Glazing

Dynamic glazing (also referred to as Smart Window or Switchable Glass) is a category of next generation glazing that works to maximize natural light and unobstructed views, while reducing heat gain and glare.

Key Considerations
- Dynamic glazing has tremendous potential in the emerging world of high performance, net zero energy buildings: it provides some of the best year round energy performance for glazing, while enabling notable glare control, personal comfort, peak load reduction and reduced materiality benefits.
- Energy Use Reduction
  - By admitting natural daylight and rejecting unwanted solar gain, dynamic glazing reduces annual energy costs.
- Glare Control
  - Solar radiation and glare are reduced when the glass is tinted, creating a comfortable indoor climate for occupants.
- Access to Daylight and Views
  - Building inhabitants enjoy the benefits of natural sunlight, like improved mood and productivity. Views are not impaired by devices such as shades or fit.
- Peak Load Reduction
  - Compared to standard low-e glazing, dynamic glazing can reduce a building’s cooling peak load as well as reduce the sizing of its HVAC equipment required to handle peak loads.
- Reduced Materiality
  - In addition to HVAC equipment reductions, dynamic glazing minimizes the need for other shade or heat control treatments such as external or internal shading devices.

Application at TSC
- Electrochromic glazing is proposed to be used on the south facade of TSC which includes 400 dorm rooms and post-security circulation. These south and southeast facing spaces have significant peak load heat and glare control situations throughout the year.
- Dynamic glazing is well suited to solve. Electrochromics is also a preferred solution for these spaces due to its unique zoning and user controllability options.

Suppliers
- Sage Glass – Faribault, Minnesota
- View Glass – Milpitas California
Drilling Down on the Experiential and Operational

Dynamic Glazing (also referred to as Smart Windows or Switchable Glass) is a category of next generation glazing that works to maximize natural light and unobstructed views, while reducing heat gain and glare.

How the technology works
Dynamic glazing works by dynamically changing the traditionally static performance characteristics of window glass such as visible light transmittance and solar heat gain coefficient. Examples of technologies that enable dynamic glazing are electrochromic (EC), thermochromic, photochromic, liquid crystal (LC) and suspended particle devices (SPD).

Thermochromic and photochromic technologies change their properties based on ambient temperature and light respectively. EC, LC and SPD technologies leverage electronic control, using low quantities of energy to manage glazing characteristics, thereby providing opportunities to integrate with building operating schedules and accommodate localized zone by zone configurations.

Key Considerations
Dynamic glazing has tremendous potential in the emerging world of high performance, net-zero energy buildings. It provides some of the best year round energy performance for glazing, while enabling notable glare control, personal comfort, peak load reduction and reduced materiality benefits.

- Energy Use Reduction
  By admitting natural daylight and rejecting unwanted solar gain, dynamic glazing reduces annual energy costs.

- Glare Control
  Solar radiation and glare are reduced when the glass is tinted, creating a comfortable indoor climate for occupants.

- Access to Daylight and Views
  Building inhabitants enjoy the benefits of natural sunlight, improved mood and productivity. Views are unimpaired by devices such as shades or blinds.

- Peak Load Reduction
  Compared to standard low-e glazing, dynamic glazing can reduce a building’s cooling peak load as well as reduce the sizing of its HVAC equipment required to handle peak loads.

- Reduced M&O
  In addition to energy savings, glazing also minimizes/eliminate glare or heat related issues.

Application of Electrochromic Glazing:

- Electrochromic Glazing used in the glazing includes a circulated, liquid, low-e situation through the dynamic glazing in order to control sunlight for unique zone or functional needs.

- Increased access to natural daylight, better views (not blurred by fit), glare control and thermal comfort.

Future Flexibility
Maximizes hold room capacity (extending adjacent to windows is possible) as well as pod reconfiguration.

Electrochromic Performance

Scenario:
Southwest orientation, estimated to be 'worst case', eg maximum glare probability over the course of the year. 3307 Annual Daylight Hours. 2279 hours of which are estimated to experience glare issues if only baseline is used.

Baseline: Tint 1, Clear Glass, Tyt 58%, Estimated Operating State – 25% daylight hours per year (3758 hours)

Tint 2, Tyt 40%, Estimated Operating State – 25% daylight hours per year (760 hours)

Tint 3, Tyt 6%, Estimated Operating State – 40% daylight hours per year (1200 hours)

Tint 4, Tyt 1%, Estimated Operating State – 10% daylight hours per year (319 hours). Results in 15 hours over year (0.05% time) with glare.
## Electrochromic LCCA

### Life Cycle Cost Assessment - BPD T1 Center Renovation - Replace Base Glazing with Electrochromic on T1 Airside Departures

<table>
<thead>
<tr>
<th>Factor</th>
<th>Value</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analysis Period (Years)</td>
<td>20</td>
<td>FE PD LCCA Requirement, Section 01 35 10</td>
</tr>
<tr>
<td>Discount (Interest) Rate</td>
<td>5%</td>
<td>LCCA Requirement, Section 01 35 10</td>
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<tr>
<td>Capital Recovery Factor (pct)</td>
<td>0.0002</td>
<td>LCCA Requirement, Section 01 35 10</td>
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<tr>
<td>Utility Erosion Rate (pct)</td>
<td>7%</td>
<td>LCCA Requirement, Section 01 35 10</td>
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<tr>
<td>Capital Stock of Carbon (Year)</td>
<td>$1,145</td>
<td>Provided by BPD email 7/20/2019</td>
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<tr>
<td>Carbon Erosion Rate (pct)</td>
<td>2.5%</td>
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</tr>
<tr>
<td>Annual Energy Reduction (%)</td>
<td>47%</td>
<td>Energy savings, $2,120 at</td>
</tr>
<tr>
<td>Area Impacted by Efficiency (ft²)</td>
<td>10,410</td>
<td>TCC &amp; T&amp;W</td>
</tr>
<tr>
<td>Total Project Area (ft²)</td>
<td>790,000</td>
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</tr>
<tr>
<td>Estimated Product Cost (COF)</td>
<td>($103,699)</td>
<td>S/SH glazing/installation increase, 17,000 sq ft (T1 airside)</td>
</tr>
<tr>
<td>Other Costs (COF)</td>
<td>($89,003)</td>
<td>LCCA Requirement, Section 01 35 10</td>
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<tr>
<td>Capital Cost (COF)</td>
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<tr>
<td>Estimated Product Cost (ROM)</td>
<td>($103,699)</td>
<td>Assumes 95% markup from ROM</td>
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<td>Capital Cost (ROM)</td>
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<tr>
<td>Electricity Savings</td>
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<tr>
<td>Gas Savings</td>
<td>$0</td>
<td>None - Assuming dynamic glazing not reducing heating requirements</td>
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<tr>
<td>Other O&amp;M Savings</td>
<td>($2,203)</td>
<td>Controls Tuning, Estimated 0 hours/quarter, $150/hour</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$185,000</strong></td>
<td><strong>($150,000)</strong></td>
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<tr>
<td><strong>NPV (RO) (20%F)</strong></td>
<td><strong>$23,727</strong></td>
<td><strong>($150,000)</strong></td>
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</tbody>
</table>

## Thermochromic LCCA

### Life Cycle Cost Assessment - BPD T1 Center Renovation - Replace Base Glazing with Thermochromic T1 Airside Departures

<table>
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**Triple Bottom Line Analysis - BAB**

<table>
<thead>
<tr>
<th>Environmental &amp; Social Impact</th>
<th>Sustainable NPV</th>
<th>Sustainable BCR</th>
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<tbody>
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<td>Financial NPV</td>
<td>Social &amp; Environmental NPV</td>
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<td>Green Roof</td>
<td>-$1,052,555</td>
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<tr>
<td>Electrochromic Glazing</td>
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<td>+ $6,255,624</td>
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<td>Motorized Window Shades</td>
<td>-$7,593,481</td>
<td>+ $6,255,624</td>
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<td>Interior Landscaping</td>
<td>-$8,480,450</td>
<td>+ $11,392,549</td>
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<td>Radiant Heating and Cooling</td>
<td>-$2,842,986</td>
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<tr>
<td>Ground Source Heat Pump</td>
<td>-$5,821,573</td>
<td>+ $594,152</td>
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**Putting It All Together:**

**IT’S A GO!**

Dynamic Glazing (also referred to as Smart Windows or Switchable Glass) is a category of next generation glazing that works to maximize natural light and unobstructed views, while reducing heat gain and glare.

**Environmental & Financial Performance**

- **EUI Reduction (kwh/ft²):** 0.6
- **Capital Cost ($):** $216,400
- **Energy Savings ($/yr):** $150,018
- **Simple Payback (yrs):** 10
- **EUI Unit Capital Cost ($/EUI):** $227,977
- **Carbon Reduction (metric ton/yr):** 0
- **Avoided Cost of Carbon (EUI):** $0

**Experiential & Operational Considerations**

- **Passenger & Employee Experience:** Optimizes passenger and employee experience with preprogrammed and on-demand glare control.
- **Health & Comfort:** Increased access to natural daylight, better views (not blurred by TYG), glare control, and thermal comfort.
- **Future Flexibility:** Maximizes hold more capacity (leasing adjacent to windows is possible) as well as podium reconfiguration.
- **Innovation Acceleration:** Dynamic glazing is an emerging technology with high potential at airports.
- **Operational Convenience:** Easy, simple cleaning. Plan for occasional software tuning to optimize performance.
- **Schedule Implications:** Procured as part of envelope/outside wall package. Delivered within normal industry timeframes.
- **Other Decision Factors:** ECVF maximum glazing module is a perceived design constraint as to color.
Departures + Mezz + Sterile Corridor

First to Launch: BAB
DFW Airport Terminal Comfort Study

- **Subjects:** 500 Total over 5 weeks A-28(View) = 250, A-25 = 250
- **Survey Method:** live, in-gate interviews
- **Evaluation Period:** 7am-11am every clear day
- **Survey Content:** 20 questions regarding comfort & seating priorities
- **Survey Integrity:** Voluntary subjects, no compensation offered
A-25 (Low-E glass)

A-28 (Smart glass)
Researcher Observation:
Gate A25 passengers show discomfort

Researcher Observation:
Gate A28 passengers work comfortably
Floor Temperatures are 15 degrees cooler
Gates A25, A28

A25 - 9:52AM
78.7°F

A28 - 9:52AM
63.4°F

Unoccupied Seat Temperatures are 12 degrees cooler

A25 - 10:03AM
89.5°F

A28 - 10:03AM
78.7°F
Hold Room Results:

- **Up to 83%**
  - longer gate dwell time near dynamic glass vs standard glass

- **3:1**
  - Preference for dynamic glass

- **#2**
  - Access to views as a gate seating priority

- **15°C**
  - Cooler temps at gate with dynamic glass

Smart glass impact on Concession Revenue
Smart glass impact on Concession Revenue

102% Increase in passenger spending (6 mo.)

Dallas Fort Worth Study Results:

- Up to 83% longer gate dwell time near dynamic glass vs standard glass
- 102% More spending at concession
- #2 Access to views as a gate seating priority
- 15° Cooler temps at gate with dynamic glass
Smart glass provides the platform for Improved Passenger Experience, Increased Revenue and Operational Efficiency

- **Increased Passenger Comfort**
  - More access to comfortable seating and views
  - Optimized environment for device & technology usage
  - More efficient/flexible space utilization

- **Increased Revenue**
  - Increased dwell time leads to more spending
  - Increase in revenue per enplanement
  - Smart Glass provides healthy project ROI

- **Operational Efficiency**
  - Reduced energy costs
  - Reduced carbon footprint - Carbon Neutral/LEED
  - Reduced maintenance costs

“When we looked at technologies that fit all three (People, Planet, Profit), that’s a win for our airport. View really fit that bill.”

- Chad Makovsky, Executive Vice President of Operations - DFW
Thank You for Participating Today!

Questions?

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