15% Of Floor Area – Or Freedom To Use More Glass
1865 DOUBLE GLAZING PATENT
(“Lincoln” Movie Year)
2014 INSULATING GLASS U-VALUE

- Single Glass
- Double Glass - Single Low-e
- Triple Glass - Double Low-e
- QuadPane - Triple Low-e
- QuintPane

Values:
- Single Glass: 1.00
- Double Glass - Single Low-e: 0.24
- Triple Glass - Double Low-e: 0.14
- QuadPane - Triple Low-e: 0.08
- QuintPane: 0.06
2014 INSULATING GLASS R-VALUE
\( (R = \frac{1}{U}) \)
Air: 1/2”
Argon: 1/2”
Krypton: 3/8”
Xenon: 1/4”
Optimal Interspace
Air, Argon, Krypton & Xenon

Window Gas Viscosity

Molecular Weight

Poise

Molecular Weight
ARGON/KRYPTON CONTAINMENT MONITORING

Argon Percentage Instantly Displayed

German Standard:
Fill To 90+% - Maintain Gas Loss Below 1% Per Year

FDR Design (Buffalo, MN) 12-Year Argon Containment < ½% Per Year

Contact: Randi Ernst: FdrDesign.com
Performance Increase Due To Gas Filling (2014 Triple Insulating Glass)

GAS IMPROVEMENT IN R-VALUE (TriPane IG / Double Low-e)

- Argon (90%) - 25%
- Krypton (90%) - 43%
- Xenon (90%) - 53%

September 2014 Price Note: Krypton Down 60% / Xenon Up 7X

R-VALUE BY GAS FILL (TriPane IG / Double Low-e)

- Air - 5.9
- Argon (90%) - 7.4
- Krypton (90%) - 8.4
- Xenon (90%) - 9.0
### Frame-Only U-Values

From: "Residential Windows"  
(Carmody/Selkowitz/Arasteh/Heschong)

<table>
<thead>
<tr>
<th>Material</th>
<th>Low</th>
<th>High</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum (no break)</td>
<td>1.7</td>
<td>2.4</td>
<td>2.05</td>
</tr>
<tr>
<td>Aluminum (thermal break)</td>
<td>0.8</td>
<td>1.3</td>
<td>1.05</td>
</tr>
<tr>
<td>Carbon Steel</td>
<td>0.40</td>
<td>0.57</td>
<td>0.49</td>
</tr>
<tr>
<td>Insulated Vinyl &amp; Fiberglass</td>
<td>0.2</td>
<td>0.4</td>
<td>0.30</td>
</tr>
</tbody>
</table>

#### WINDOW FRAME AVERAGE U-VALUE

- **Aluminum (no break):** 2.05
- **Aluminum (thermal break):** 1.05
- **Carbon Steel:** 0.49
- **Insulated Vinyl & Fiberglass:** 0.30
Fading

Overheating

Too cold on cloudy winter days

Undercooking

Moveable Insulation Burden

Daily temperature swings

Lack of privacy or security

Glare
“Most designers feel safer specifying low-solar-gain glazing for the west elevation.”

Martin Holladay
GreenBuildingAdvisor.com
End Of Empirical Testing For Commercial Windows (?)

CMAST = Component Modeling Approach Software Tool

ACE = Approved Calculation Entity
University Of Colorado - $63 Visual Arts Center

Super IG + 131” Pultrusion FG Frames

Architects: KMW-Boston & OZ-Colorado

Woodbury Hall – 1890 – Original Steel – to Interim Aluminum – to Serious Fiberglass
2007 Top-10 Green Building Product
GreenSpec
www.BuildingGreen.com
Passive House Occupant Comfort

Six Human Comfort Factors

1. Air Temp
2. Mean Radiant Temp
3. Air Velocity
4. Relative Humidity
5. Activity Level
6. Clothing Factor
Passive House Occupant Comfort

CFD Modeling
**Insulating Glass "Passive Performance Coefficient"**

<table>
<thead>
<tr>
<th>CONFIGURATION</th>
<th>LI-HM88-LI (Ar)</th>
<th>LI-2HM88-LI (Kr)</th>
<th>C180-2HM88-LI (Kr)</th>
<th>Dbl C180 + 3HM88 (Xe)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outer Light</td>
<td>1/8&quot; Low Iron</td>
<td>1/8&quot; Low Iron</td>
<td>1/8&quot; Low Iron</td>
<td>1/8&quot; C180 (#2)</td>
</tr>
<tr>
<td>Triple Versus QuadPane</td>
<td>Quad</td>
<td>Quad</td>
<td>Quad</td>
<td>Quint</td>
</tr>
<tr>
<td>Interspaces</td>
<td>2 @ 1/2&quot; Argon</td>
<td>3 @ 3/8&quot; Krypton</td>
<td>3 @ 3/8&quot; Krypton</td>
<td>4 @ 1/4&quot; Xenon</td>
</tr>
<tr>
<td>(SFC) Suspended Coated Film</td>
<td>HM88</td>
<td>Double HM88</td>
<td>Double HM88</td>
<td>Triple HM88 (#4,6,8)</td>
</tr>
<tr>
<td>Inner Light</td>
<td>1/8&quot; Low Iron</td>
<td>1/8&quot; Low Iron</td>
<td>1/8&quot; Low Iron</td>
<td>1/8&quot; C180(#9)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PERFORMANCE</th>
<th>U-Value (Winter)</th>
<th>R-Value</th>
<th>Solar Heat Gain Coefficient</th>
<th>&quot;PPC&quot; Passive Performance Coefficient</th>
<th>Tvis</th>
<th>UV Blockage (to 380 nm)</th>
<th>ASHRAE/NFRC &quot;Winter&quot; Glass Temp (F)</th>
<th>ASHRAE/NFRC &quot;Summer&quot; Glass Temp (F)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.20</td>
<td>5.0</td>
<td>0.60</td>
<td>3.0</td>
<td>74%</td>
<td>99.3%</td>
<td>59 Deg F</td>
<td>91 Deg F</td>
</tr>
<tr>
<td></td>
<td>0.11</td>
<td>9.3</td>
<td>0.51</td>
<td>4.7</td>
<td>66%</td>
<td>100.0%</td>
<td>83 Deg F</td>
<td>94 Deg F</td>
</tr>
<tr>
<td></td>
<td>0.08</td>
<td>12.2</td>
<td>0.44</td>
<td>5.3</td>
<td>63%</td>
<td>100.0%</td>
<td>65 Deg F</td>
<td>90 Deg F</td>
</tr>
<tr>
<td></td>
<td>0.050</td>
<td>20.0</td>
<td>0.38</td>
<td>7.5</td>
<td>53%</td>
<td>100.0%</td>
<td>67 Deg F</td>
<td>96 Deg F</td>
</tr>
</tbody>
</table>

All values are Center Of Glass - as calculated by LBNL Window 6 Software

**"PPC" = PASSIVE PERFORMANCE COEFFICIENT = SHGC/U-VALUE**

- Low Iron Glass (no green)
Institutional/Commercial Passive House Presence

NRDC Headquarters - NYC

Morristown Maple Avenue City Building
### Empire State Building Before And After Glass Performance

<table>
<thead>
<tr>
<th>North Elevation (Fifth Avenue Orientation: 29 1/2 Degrees East Of North)</th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outer Light</td>
<td>Clear Uncoated Double Pane (1992)</td>
<td>&quot;Triple&quot; SCF Glass Suspended Coated TC88</td>
</tr>
<tr>
<td>Interspaces And Thickness</td>
<td>3/16&quot; Clear</td>
<td>3/16&quot; Clear</td>
</tr>
<tr>
<td>Suspended Coated Film(s)</td>
<td>1 @ 5/8&quot;</td>
<td>2 @ 5/16&quot;</td>
</tr>
<tr>
<td>Gas Fill</td>
<td>None</td>
<td>TC-88 (Double Low-e)</td>
</tr>
<tr>
<td>Inner Light</td>
<td>3/16&quot; Clear</td>
<td>3/16&quot; Clear</td>
</tr>
</tbody>
</table>

#### Performance

<table>
<thead>
<tr>
<th></th>
<th>Before</th>
<th>After</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>U-Value</td>
<td>0.48</td>
<td>0.13</td>
<td>-72%</td>
</tr>
<tr>
<td>R-value</td>
<td>2.1</td>
<td>7.6</td>
<td>+261%</td>
</tr>
<tr>
<td>SHGC</td>
<td>0.72</td>
<td>0.49</td>
<td>+32%</td>
</tr>
<tr>
<td>Tvis</td>
<td>80%</td>
<td>64%</td>
<td>-20%</td>
</tr>
<tr>
<td>Winter NFRC (70 in/0 out/15 mph) Glass Temp</td>
<td>44 Deg F</td>
<td>62 Deg F</td>
<td>+ 18 Degrees F</td>
</tr>
<tr>
<td>Summer NFRC (75 in/90 out) Glass Temp</td>
<td>95 Deg F</td>
<td>76 Deg F (LBNL)</td>
<td>- 19 Degrees F</td>
</tr>
<tr>
<td>Overall Thickness</td>
<td>1&quot;</td>
<td>1&quot;</td>
<td>No Change</td>
</tr>
<tr>
<td>UltraViolet Blockage</td>
<td>46.8%</td>
<td>98.6%</td>
<td>-111%</td>
</tr>
</tbody>
</table>
EMPIRE STATE BUILDING SCF
GLAZING RENOVATION

Windows: 6,514
IG Units: 13,028
Glazing: ~160,000 ft²
Start: March, 2010
End: November 2010

<table>
<thead>
<tr>
<th>ESB Renovation Measure Contributions</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1) DDC (Direct Digital Control)</td>
<td>603</td>
<td>36.8%</td>
</tr>
<tr>
<td>2) Demand Controlled Ventilation</td>
<td>5</td>
<td>0.3%</td>
</tr>
<tr>
<td>3) Tenant Lighting &amp; Plug Load Reduction</td>
<td>424</td>
<td>25.9%</td>
</tr>
<tr>
<td>4) Windows</td>
<td>440</td>
<td>26.9%</td>
</tr>
<tr>
<td>5) Tenant Energy Management</td>
<td>166</td>
<td>10.1%</td>
</tr>
<tr>
<td>Total Tonnage Reduction</td>
<td>1,638</td>
<td>100.0%</td>
</tr>
<tr>
<td>Total Avoided HVAC (Chiller) Expenditure</td>
<td>$ 17,400,000</td>
<td></td>
</tr>
<tr>
<td>Windows Share Of Chiller Savings</td>
<td>$ 4,673,993</td>
<td></td>
</tr>
</tbody>
</table>

So, by GSB Valedictorian Mel Hodge Logic, payback is: "Immediate"
$/Ton Savings 10,623 (High?)
Manufacturing Innovation
Reuse Of Existing Glass

Production/Installation Capacity:
35-50 Windows/Night

Traco 9000 Windows Identical To Those Of 111 8th Avenue
**Performance:**

- **U-Value**: 0.48
- **R-value**: 2.1
- **SHGC**: 0.72
- **Tvis**: 80%

**Winter NFRC Glass Temp** (70 in/0 out/15 mph)  
44 °F

**Summer NFRC Glass Temp** (75 in/90 out)  
95 °F

**Overall Thickness**: 1"

**Ultra Violet Blockage**: 46.8%
Performance:

<table>
<thead>
<tr>
<th>Performance</th>
<th>After Retrofit</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>U-Value</td>
<td>0.13</td>
<td>-72%</td>
</tr>
<tr>
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</tbody>
</table>

EMPIRE STATE: After

NORTH

3/16” thick glass panes
Cleaned and re-used from old IGs

New suspended coated film
“Twin-Coated” film (low-e coatings front & back)

Two 5/16” wide gas-filled cavities
Blend of 90% krypton / 10% air
SCF North-South-East-West “Tuned” Glazing
Fiberglass Storefront In High Humidity Galleries
99.9% UV Blockage
62 Degree “Winter” Glass Temp
Perimeter Baseboard Heating Removal
Payback Under One Year
LEED PLATINUM FIBERGLASS WINDOWS & SCF GLASS

- Pultrusion Fiberglass Casement Frames
- 1 3/8” SCT Glazing Pocket For Thermal & Acoustic Performance
  - R-8 SCF Glass
- Warm Winter / Cool Summer

- Directionally “Tuned” SCF Glass
  - 99.5% UV Blockage
  - Inside/Outside Color Freedom
- 1/500th Aluminum Frame Conductivity
  - High Volume Pricing
FIBERGLASS CROSS-SECTION

Pultrusion Lineal Mechanical Corner Sash

Pultrusion “End” (Al Dueck – Duxton)
COMMERICAL FIBERGLASS FRAMES

Internal Anchor Blocks

Winnipeg Church In Blizzard – Warm To The Touch Window Frames
9th PASSIVE HOUSE CONFERENCE WINDOW COMPANIES
“European” High End Windows – (Denver Passive House)

Average Frame + Sash Width: 4.9”
Zola Windows
Passive House Windows
ZolaWindows.com
OptiWin
Passive House Windows
OptiWin-Usa.com
NorthWin
Passive House Windows
Northwin.com

Certificate
Certified Passive House Component
for cool, temperate climates; valid until 31.12.2013

Category: Window Frame
Manufacturer: Northwin windows and doors inc.
V6P 6R9 Vancouver, CANADA
Marvin Ultimate Windows
Passive House Certified
(Zone 3 & Marine South)

Glass Options: Tri-Pane & Quad Pane Heat Mirror®
Casa Grande Woodworks
Passive House Certified
CasaGrandeWoodworks.com
Alpen Windows
Passive House Certified
AlpenHpp.com

Glass Options: Alpengllass Heat Mirror Tri & Quad Pane
Lower Profile North American High Performance Vinyl Windows

Average Frame + Sash Width: 2.75
GRHAM WRIGHT
R-9 Window Design

- Frame
  - Wood and spray foam
  - Width 90 mm
  - Depth 140 mm (5.5”)

- Glazing
  - 4-pane, 90% Argon, 50 mm
  - Cardinal lo-e 180 and clear

- Spacers
  - Chromatech Ultra F

“I feel glazing is not the limiting factor for window performance at this time, but rather frame design.”
FIBERGLASS WINDOW
SASH/FRAME CROSS SECTION

TectonProducts.com
InlineFiberglass.com
OmniGlass.com
VACUUM SILICA BASED SASH/FRAEME R-40 INSULATION

KevoThermal.com – Albuquerque (9/14/14 Update)
2014 Passive House Window “Core” Insulation
Pricing: $7-$10/SF = $2.13/Lineal 3” x .33” Strip
Effective R-Value: 13.5
### REPRESENTATIVE STC RATINGS

<table>
<thead>
<tr>
<th>GLAZING TYPE</th>
<th>SOUND TRANSMISSION CLASS (STC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional Double Pane (1/8”) Glass</td>
<td>29</td>
</tr>
<tr>
<td>Solid ½” Gypsum Wall</td>
<td>36</td>
</tr>
<tr>
<td>SCF: 1” Overall with ¼” Glass</td>
<td>35</td>
</tr>
<tr>
<td>SCF: 1 ½” Overall with ¼” Glass</td>
<td>38</td>
</tr>
<tr>
<td>SCF: One Lite Laminated</td>
<td>40</td>
</tr>
<tr>
<td>SCF: Two Lites Laminated</td>
<td>43</td>
</tr>
<tr>
<td>SCF: Two Dissimilar Laminated Lites</td>
<td>49</td>
</tr>
<tr>
<td>SCF: Two ”Acoustic“ Laminated Lites</td>
<td>52</td>
</tr>
</tbody>
</table>
TEST WINDOW:
87 Wide x 72” High
Two large upper fixed
One small fixed and one small awning below
Insulating Glass
Outer: ¼”
Airgap: ¾”
Inner: 3/16”

National Research Council of Canada Inline Fiberglass Window Acoustic Report (STC = 35)
COMMERCIAL FIBERGLASS CURTAINWALL
100% Fiberglass Framing (22’ Height)

Infra Red (Interior) With New Aluminum Insulated Door

Colorado State University Power Center
DYNAMIC GLAZING
Electrochromic / Photochromic / Thermochromic
BIPV GLAZING
Integral PV Cells / Transparent PV

Onyx Solar - (Spain)

Pythagoras Solar
TRANSPARENT SOLAR CELL – CLEAR PV WINDOW

- Michigan State University
- Organic Salts Absorb UV & IR – and emit IR
- Direct to perimeter standard PV cells
- 1% efficiency – target 5%

Also…

Atlantis Solar – NY
Pythagoras – Bay Area
R-3 Window & R-39 Walls Equate To R-7 Windows & R-18 Walls

Target: Keep All Window Surfaces At Or above 60F

Mean Radiant Temperature OVERWELMS All Other Contributors To Occupant Comfort

All Windows Need External Shutters

| R-29 To R-18 Net Area Increase (R-7/Inch; 3" Reduction) |
|----------------|----------------|
| Floor Area: 2000 | 2000         |
| Width           | 40           |
| Depth           | 50           |
| Perimeter       | 180          |
| Net Wall Reduction | 0.25        |
| Increased Interior Space | 45          |
| Value/SF        | 250          |
| Realized Increased Value | $ 11,250   |
Amory Lovins: *All of the energy pumped through the Alaska Pipeline each year goes literally “out America’s windows.”*