Selecting the Ideal Windows for a High Performance Home in a Cold Climate

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Session Overview

• To look at results of evaluation of window performance for a net zero energy production house in a cold climate

• Key evaluation criteria:
  – Market availability
  – Constructability & Durability
  – Cost vs. Energy performance
  – Comfort

• Summary of results and next steps
Our Challenge - A Net Zero Energy House that is Mainstream, Production

Selecting the Ideal Windows in a Cold Climate
Specifications of Net Zero House Design

- R-60 attic
- R-26 basement foundation
- R-10 under-slab
- R-31 wall cavity with R-10 exterior sheathing (R-41 total)
- Air infiltration 0.00003 SLA (0.6 ACH50)
- GSHP with de-superheater for domestic hot water
- Ductwork within conditioned space, 0% leakage to outdoors
- Energy recovery ventilation system
- 100% high efficacy lighting
- All Energy Star appliances
- PV system – approx. 9 kW system needed for net zero

Windows?
Evaluation Criteria – Must Meet

- Minimum Energy Performance Specification
- Code Acceptance
- **Market Availability of the Technical Solution(s)**
- Constructability
- Trade skill set change
- Functionality
- Architectural Flexibility
- Scalability Potential
- Durability: Moisture Management
- **Cost vs. Energy Savings Ratio**
Evaluation Criteria – Should Meet

- Homeowner Impact
- Systems Integration and Elimination Potential
- Environmental Responsibility
- Cycle Time
- Durability and Maintenance
- Comfort
Evaluation Process

• Technical solution is given a ranking depending on how well it meets the criteria requirements
• Each criterion is assigned a weight value based on its importance
• The rank of each technical solution is multiplied by this weight, resulting in a weighted ranking
• The weighted rankings are totaled for each technical solution with the highest total score becoming the first system choice
Define Target Performance

- Efficient Windows Collaborative (www.efficientwindows.org)
  - Window Selection Tool: Pittsburgh, PA, USA
  - Total Unit U-value of 0.18 BTU/hr·F·ft² (3.7 kJ/hr·m²·K)
  - Total Unit Solar Heat Gain Coefficient (SHGC) of 0.40
Many favorable high performance window products were marketed as replacement window products only.

Supply chain well-defined for replacement market, but still undefined for new home market.

Options available for new construction (snap on nailing fins, integral J-channel, etc.), but not standard.

Some window products only available factory-direct for new construction.
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Constructability & Durability – Must Meet

- Varying availability of details, components, instructions, and installers for each product.
- Builder input:
  - Make sure installation of windows is not complicated and product is readily available
  - Ensure windows integrate well with cladding materials
• Lack of adequate manufacturer details
  – Installing window in wall with thickened layers of exterior foam sheathing (2 – 4”)
  – In general, U.S. manufacturers had little knowledge of installation with exterior foam sheathing
  – In general, Canadian manufacturers had experience with this type of installation, but had no documented details to share
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- Look at installation details in thickened wall assemblies

- How to best integrate window with drainage plane
  - In plane with exterior sheathing
  - Inset in wall cavity
• Minimum of half the width of the window frame must bear upon solid wood framing
• With 2” XPS sheathing a ½” OSB buck needs to be installed at the sill of the framed opening. Rough opening size needs to be adjusted
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Constructability & Durability – Window Installation

• Window nailing flanges need to be secured through foam sheathing directly to wood framing with minimum 1 ½” penetration into solid wood base

• Integral nailing flanges and J-channel very important in production building
• Examine window placement within the wall assembly
• Manufacturers suggest recessed/interior placement to keep them warmer
• Flashing details for exterior mounted window similar to typical sheathing case
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- Window placement within center/interior mount requires recessing XPS & more flashing detailing, materials
- Exterior placement of window favored for constructability
Initially conducted U-value and SHGC optimization modeling

- EnergyGauge® USA (version 2.8.01)
- 2722 ft² house, Northwest orientation, two-story
- Assumed same window performance on all orientations
- Prominent Southwest (long axis) exposure, no Northeast exposure
U-value Optimization

- Pittsburgh, PA weather data
- U-values between 0.10 and 0.50
- SHGC held constant
- Lower U-value = Lower annual heating energy use
- Total annual heating/cooling energy use mirrors total annual heating energy
SHGC Optimization

- Pittsburgh, PA weather data
- SHGC between 0.10 and 0.70
- U-value held constant (0.18)

- Heating energy decreases as SHGC increases (passive heating)
- Cooling energy increases as SHGC increases (greater solar gain)
- Total heating/cooling energy optimizes between 0.40 and 0.50 SHGC, settling at 0.46
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- U-value performance is more significant than SHGC in determining potential energy savings in a cold climate
- Ideal window for cold climate (Pittsburgh, PA) should have low U-value (<0.20) and SHGC around 0.46
  - Survey of window manufacturers revealed limited availability of windows with these performance values
  - Existing window products that met these specifications were more expensive (i.e. fiberglass frames, triple-pane glazing, Krypton or Xenon gas fills)
  - Most existing window products with these specifications were manufactured in Canada, with very few domestic U.S. products being produced
Cost vs. Energy Performance – Must Meet

- In general, window products with U-values below 0.20 are uncommon
- More common are windows with U-values between 0.20 and 0.30
  - However, the majority of windows with these U-values also had SHGC ratings between 0.20 and 0.30
  - Both U.S. and Canadian window products available
  - Cost more reasonable in comparison to builder’s standard window product (lower incremental cost)
Since U-value has more influence on annual heating/cooling energy use than SHGC, window products with SHGC ratings between 0.20 and 0.30 were focused on.

Selection of windows for detailed analysis included products with 2- and 3-pane glazing (either glass or suspended-film third pane); vinyl, fiberglass and composite framing; insulated and un-insulated frames – U-values between 0.17 and 0.28 – SHGC ratings between 0.16 and 0.47 – Visible Transmittance (VT) ratings between 0.36 – 0.50
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- TRNSYS (6 min time step) for energy and comfort determination
- Best Cost vs Energy Savings Ratio:
  - Window E – Double-glazed with suspended film, krypton gas fill; vinyl frame; U=0.22; SHGC=0.33
  - Window B – Triple-glazed with suspended film; krypton gas fill; fiberglass-reinforced vinyl frame; U=0.17; SHGC=0.16

Cost vs. Energy Savings Ratio for Windows

<table>
<thead>
<tr>
<th>Window</th>
<th>Incremental Cost per Unit Energy Savings ($/kWh)</th>
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</thead>
<tbody>
<tr>
<td>A</td>
<td>$13</td>
</tr>
<tr>
<td>B</td>
<td>$7</td>
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<tr>
<td>C</td>
<td>$13</td>
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<td>D</td>
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<td>$5</td>
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<td>F</td>
<td>$20</td>
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<tr>
<td>G</td>
<td>$19</td>
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<tr>
<td>H</td>
<td>$11</td>
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• Considered “Should Meet” but is highly important to building occupants

• Top five window options evaluated more closely with respect to:
  1. Thermal Comfort Performance Index (TCPI)
  2. Visible Transmittance (VT)
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- Indicates thermal comfort conditions in each zone of house
- TRNSYS simulations to calculate average whole house TCPI value per window system
- Value between 98% and 100% is preferable

TCPI Value

<table>
<thead>
<tr>
<th>Window</th>
<th>TCPI Value</th>
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<tbody>
<tr>
<td>Base Window</td>
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<tr>
<td>Window A</td>
<td></td>
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<tr>
<td>Window B</td>
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<td>Window E</td>
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<td>Window F</td>
<td></td>
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<tr>
<td>Window H</td>
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- **Highest TCPI:**
- Window B – Triple-glazed with suspended film; krypton gas fill; fiberglass-reinforced vinyl frame; U-0.17; SHGC-0.16; VT-0.36
- Window H – Double-glazed; krypton gas fill; vinyl frame; U-0.25; SHGC-0.27; VT-0.44
• **Visible Transmittance**
  
  • Percentage of light from visible spectrum passing through window
  
  • Higher VT = greater visibility = higher visible comfort for occupants
  
  • VT ≥ 0.50 is ideal for cold climate
  
  • VT < 0.40 is restrictive to vision
  
  • Window B has VT of 0.36 and is likely too dark for a cold climate (based on visual inspection) & unacceptable to homeowners
  
  • Window H has VT of 0.44 and is acceptable for a cold climate
Conclusion

• Window H was selected as the ideal window for our cold climate net zero energy house because:
  – Superior comfort-related performance, good VT level
  – Affordable, available, and scored highest for constructability due to standard installation features of integral nailing flanges and J-channel

• Window H has:
  – U-value is average for windows evaluated (0.25)
  – SHGC was also average (0.27)
In summary, the ideal window selection for a net zero energy, cold climate house:

– Balances thermal performance with affordability (U-value more important than SHGC)
– Is available with typical installation features for new construction production housing like integral nailing flanges and J-channel
– Provides VT levels that homeowners should find acceptable
Next Steps

• Expand modeling evaluation to include greater number of high performance windows particularly energy efficiency leaders

• Perform evaluation for other climate zones

• Spread the word that there is a strong need for high performance windows in the cold climate that are suitable for the new construction production market.
Thank You

Any Questions?
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