Evaluating R-40 Above-Grade Walls for a Production Built Net Zero Energy House

Co-Author/Presenter: John Broniek
Co-Authors: Kevin Brozyna and Dave Stecher
Session Overview

• Findings, challenges, and lessons learned during research in above-grade walls for a net zero energy house
• Cold climate solutions for production homebuilding
• Evaluation process used in our research
• Key evaluation criteria:
  • Constructability
  • Cost effectiveness
  • Durability
  • Comfort
• Evaluation results
Plenty of Custom Built Net Zero Energy Houses Around

Evaluating R-40 Above-Grade Walls
Our Challenge - A Net Zero Energy House that is Mainstream, Production

Evaluating R-40 Above-Grade Walls
Specification of a Net Zero House Design in Pittsburgh

- R-60 attic
- R-26 basement foundation
- R-10 under slab
- Vinyl windows with U=0.25, SHGC=0.27; krypton gas fill
- Air infiltration 0.00003 SLA (0.6 ACH50)
- GSHP with desuperheater for domestic hot water production
- 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

Above Grade Walls?
• Minimum energy performance specification
• Code acceptance
• Market availability of the technical solution(s)
• **Constructability**
• Trade skill set change
• Functionality
• Architectural flexibility
• Scalability potential
• **Cost vs. energy savings ratio**
• **Durability: moisture management**
Evaluation Criteria: Should Meet

- Homeowner impact
- Systems integration and elimination potential
- Environmental responsibility
- Cycle time
- Durability and maintenance
- Comfort
Evaluation Criteria 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
Initial Wall Design Considerations

- Initial modeling found R-40 plus or minus R-10 nominal thermal performance required to achieve goals.

- For wood framed wall systems, the exterior insulating sheathing considered most suitable was un-faced extruded (XPS) polystyrene:
  - Compatible with different siding systems, durable
  - Cost effective, lower cost per R-value than polyisocyanurate
  - High R-value per thickness (compared to EPS)
  - Higher vapor permeability for 1” and 2” un-faced XPS compared to polyisocyanurate gives wall greater drying potential.
Focus on These Wall Systems

- A production homebuilder could potentially use all of them

- Staggered stud 2x8 and 2x6 framing limit thermal bridging

- Double wall with two rows of 2x4 studs for a lot of cavity insulation

- 2x6 stud with 1” plus of insulating sheathing to limit thermal bridging

- SIPS (Structural Insulated Panel System) as “emerging” option
Cavity Insulation Choices

- Choices have variable cost, airtightness, and permeability and are readily available
  - Blown fiberglass, R-23 to R-33 depending on thickness
  - Closed cell polyurethane spray foam, R-6.6 to R-33 depending on thickness
  - Expanded polystyrene core in SIPS, R-32 to R-43 nominal for total system

Evaluating R-40 Above-Grade Walls
2x8 Staggered Stud Wall with XPS Sheathing

- Double top plate
- 2x8 wall
- 2x4 staggered studs
- 24" O.C. spacing (front and back)
- R-31 BIBS
- 1" XPS
- Vinyl siding
- Single bottom plate

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2x6 Stud Wall with XPS Sheathing

- Double top plate
- 2x6 wall, 24" O.C. spacing
- R-23 BIBS
- 3" wide by 3/4" thick furring strip
- 3" XPS
- Composite siding
- Single bottom plate
Double Stud Wall (2x4s)

- Double top plate
- Double 2x4 wall
- Staggered studs
- 24" O.C. spacing
- R-33 or R-31 BIBS
- Interior and exterior walls placed in direct contact or spaced with 1" gap
- 1" XPS
- Vinyl siding
- Single bottom plate

Evaluating R-40 Above-Grade Walls
### List of 17 Wall Systems Studied

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<thead>
<tr>
<th>Staggered stud 2x8, blown fiberglass with...</th>
<th>1. R-5 insulating sheathing</th>
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<td>2. R-10 insulating sheathing</td>
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<td>3. R-10 insulating sheathing and layer of SPF</td>
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<td>5. 1-inch spacing; R-5 insulating sheathing</td>
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<td>8. Staggered stud; R-10 insulating sheathing</td>
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<td>2x6, layer of closed cell spray polyurethane with...</td>
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<td>11. R-15 insulating sheathing</td>
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<td>2x6, blown fiberglass with...</td>
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<td>15. R-20 insulating sheathing</td>
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<td>SIPS</td>
<td>16. 8 ¼ in. thick</td>
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<td>17. 10 ¼ in. thick</td>
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Constructability Research

• 1½-story mock-up structure in IBACOS facility
• Split mock-up into 2x8 staggered stud wall and 2x6 wall with high levels of insulating sheathing
• Evaluate:
  – Framing approaches and requirements, particularly for studs, top plates, and wall bracing
  – Attachment of varying thicknesses (1”-4”) of exterior insulating sheathing
  – Fastening of cladding over the sheathing
  – Water management strategies for the wall system
Mock-up for Wall Research

Evaluating R-40 Above-Grade Walls
• Gain practical experience with different approach
• Only need one flush face for 2x8 system
• 2x8 members used at rough openings
• Some more initial layout required than 2x6 full stud system
• Overall, 2x8 staggered stud easier to build than first thought
Wall Framing Approach

• Examine framing details for windows and inside corners with 24” o/c studs
• Double top plates simplified load bearing preferred for production building; only 10 kWh/yr energy penalty vs single top plate when R-10 insulating sheathing used
Wall Sheathing Issues

- Providing shear capacity is only one issue; OSB is preferred
- How many layers of XPS insulating sheathing are needed to achieve required thickness?
- What fasteners are needed?
- Do long fasteners drift and miss the framing?
- How is siding applied? To what?
• For 2” XPS and greater, cap screws and washer head screws used

• When using multiple layers of XPS, only outer layer needs to satisfy manufacturer’s attachment requirements

• More sheathing = greater drift from longer screws
Typically used in basements has recessed channels
Application transferred to walls
Flush surface good for backing of cladding, especially vinyl siding
More expensive than typical XPS
Alternative Insulating Sheathing

- OSB furring strips at 24” o.c. fastened to studs
- For 2” XPS, 3¼” nail with pneumatic gun used, eliminating need for screws, reducing cost, and simplifying installation
- Hot knife cutter for furring channels allowed for trim and siding nail base
Wall Durability

- Housewrap for bulk water management
- Attached to furring strips
Cladding Considerations

- Cement fiber, vinyl and wood siding installed to recessed furring strips
- 24” o.c. attachments stable
• Taped joints and surface-applied furring provide excellent drying
• Horizontal tape joint quality and insect screen critical to success
• Screws needed to install furring strips (nails not long enough) for 2” XPS or greater
• Ventilated claddings need to be stiffer to span air space
• Vinyl siding installation OK at 24” o.c.
Window Durability

- Flashing details for exterior mounted window similar to typical sheathing case were preferred
- With 2” XPS insulating sheathing, a ½” OSB buck needs to be installed at the sill of the framed opening and the rough opening size needs to be adjusted
- Recessing windows made flashing and insulation details onerous
Door Durability

- Door positioned to the exterior and had jamb and threshold extensions
- Sill pan adapted for thick wall
• TRNSYS used for energy use
• #1: 2x6 wall, R-20 sheathing
• #2: 2x6 wall, 1" spray polyurethane, R-15 sheathing
• #3: 2x6 wall, polyurethane foam, R-10 sheathing
• #4: Staggered stud 2x8 wall, R-10 sheathing
• #5: 2x6 wall, R-15 sheathing
Evaluating R-40 Above-Grade Walls

- Ratio with respect to 2x6 R-23 wall
- #1: 2x6 wall, R-5 sheathing
- #2: Staggered stud 2x8 wall, R-5 sheathing

Also:
- Double wall, R-5 sheathing
- 2x6 wall, R-10 sheathing
- 2x6 wall, R-5 sheathing, 1” SPF
• Bulk water durability findings came in constructability research.

• WUFI and Therm modeling showed that systems with XPS insulating sheathing and spray polyurethane in wall cavities should have the fewest moisture problems due to lower condensation potential.
• Indoor comfort conditions for each house design zone

• The five leaders in energy efficiency were also leaders in comfort, having the highest Thermal Comfort Performance Index (TCPI) values

• TCPI value of 100% indicates perfect comfort at all times
Final Evaluation Results

- Best score: 2x6 wall system with R-5 insulating sheathing
- Second best score: 2x6 wall system with a layer of closed cell spray polyurethane foam and R-5 insulating sheathing
- Third best score: Staggered stud 2x8 wall with R-10 insulating sheathing (then 2x6 walls with R-10 and R-15)
- Of the top three, the staggered stud 2x8 wall with R-10 insulating sheathing offers the greatest amount of heating and cooling energy savings for the whole house, saving an additional 379 kWh/yr (17%) in energy use than the first wall and 313 kWh/yr (14%) more than the second wall
Final Evaluation Results

- The staggered stud 2x8 wall with R-10 insulating sheathing did not have the lowest evaluation score.
- It has merit as a wall system for a net zero energy house.
- It was leading energy efficiency; constructability issues resolved during mock-up research.
- We will use 2x8 wall with R-10 insulating sheathing (recessed channels) design in the field.
- Overall energy usage is important for net zero energy house construction and must be considered.
Thank You

Any Questions?
jbroniek@ibacos.com