Background/Building Energy Use

- Residential and commercial energy use
- 120 million housing units (current existing stock); 70% built before energy codes
- Greatest concentration of oldest housing stock in Northeast/Midwest (heating-dominated)

Residential Exterior Wall Superinsulation Retrofit Details and Analysis

Exterior Insulation Retrofits

- Residential wood-frame walls
- Going beyond nominal R-13/R-19 walls (R-8/R-13 whole-wall R values)
- Exterior retrofit advantages
  - Insulation outboard of vulnerable structure
  - Interior is habitable during retrofit
  - Retain interior finishes (lose exterior finishes)
  - No loss in interior square footage
  - Can inspect condition of enclosure (during cladding removal)
  - Exterior stairwells (code minimum widths)

Previous Work (Exterior Retrofits)

- Insulation exterior to structure well-established technique (Hutcheon, Baker and Makepeace, Lstiburek, CCHRC)
- Dumont & Orr “Chainsaw Retrofit” 1987 (R-40+ enclosure; 3.0 ACH 50 → 0.3 ACH 50)
- ORNL 2007 hot box & airtightness measurements of exterior insulation; included foam up to 1” thick (10-15% energy savings)

Overview of Case Study Houses

- Concord, MA “Four Square”
  - Single family house 2800 + 800 sf circa 1915
  - Local energy-conscious general contractor
  - All new mechanicals

- Arlington, MA “Duplex”
  - Duplex (over/under) 1280 + 1800 + 1280 sf circa 1930
  - Local energy-conscious general contractor
  - Retained steam system

- Bedford, MA “Farmhouse”
  - Single family house 1500 + 1060 sf circa 1890
  - Habitat for Humanity (volunteers & technical high school)
  - All new mechanicals

4” Polyisocyanurate Foam
“Innie” and “Outie” Windows

- “Outie” Advantages
  - Simpler drainage plane connections/geometry
  - Lower cost (extension trim is interior material)
  - Similar appearance to conventional construction
  - Simpler window replacement

Recommend placing drainage plane at window location (whichever method used—innie or outie)!
**“Innie” vs. “Outie” Windows**

- **“Innie” Advantages**
  - Window supported by lumber frame (foam install)
  - Greater protection from wind-driven rain (inset)
  - Less condensation risk (?)
  - Thermal performance (?)
  - Can use existing window trim
  - Solar shading (advantage or disadvantage)

**Retrofitting Exterior Air Barriers**

- **St. Agatha, ON**
  - ~1 ACH 50
  - Spray foam on exterior; all windows well air sealed; casement/awning typical

- **Utica, NY (NYSERDA)**
  - 2.3 ACH 50
  - Rigid air barrier layer under foam/over board sheathing; spray foam roof-wall & barrier joint (non-“chainsaw”)

- **Belmont, MA**
  - 0.9 ACH 50
  - Rigid foam as air barrier, “chainsaw” retrofit of roof overhangs/soffits, meticulous air barrier, blower door tests in progress

**Retrofits and Water Intrusion**

- Generally improves wall durability
  - Rebuilt drainage plane; redundant layers
  - Ventilated drainage gap (3/4” cavity)
  - Reduced risk of interstitial condensation
- Reduced vapor permeability due to foam
  - Reduced drying to exterior of bulk water events
  - Reduced airflow → reduced drying?
- Hygrothermal simulations of “survivable” leak in pre- & post-retrofit walls
  - Limited applicability—“bounding exercise”

**Retrofitting Exterior Air Barriers**

- **Concord, MA**
  - “Four Square”
  - 3.1 ACH 50
  - Mechanical penetrations, porch attachments, replacement sash windows

- **Arlington, MA**
  - “Duplex”
  - 5.0 ACH 50
  - Basement compartmentalized? (1000 CFM 50 vs. 2129 CFM 50 total)

- **Bedford, MA**
  - “Farmhouse”
  - 6.2 ACH 50
  - No secondary air barrier (housewrap w. connections); mediocre roof-wall connections
“Survivable” leak (Existing Wall)

0.5% incident rain penetration → 20-25% peak north MCs
1% incident rain penetration + 35-40% peak north MCs → “unsurvivable” leak

0.5% Leak in Retrofit Wall

0.5% incident rain penetration → upwards “ratcheting” wood MCs

0.25% Leak in Retrofit Wall

Reducing rain leakage to half (0.5%) keeps wood MCs stable; same range as existing wall. Rain control critical for retrofits.

More permeable exterior rigid insulation? XPS → minimal.

EPS → Improvement

Economic Analysis

- Diminishing returns at greater insulation levels
- Original analysis $4/gallon → $2.50-$3.50/gal
- $4/sf incremental cost of opaque wall upgrade not including recladding costs
- Airtightness as part of calculated energy benefit

<table>
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<th>Oil $</th>
<th>Install cost</th>
<th>Annual Savings</th>
<th>Simple Payback</th>
<th>Payback w/o airtight</th>
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Conclusions

- Excellent opportunity for retrofit during periodic exterior cladding replacement
- Air barrier detailing and technology can use improvement; examine more options
  - Fully adhered membrane
  - Exterior spray foam
- Impermeable exterior insulation reduces available drying

Questions?

kohta@buildingscience.com
4-½” High Density Spray Foam

Cladding Support over Foam

Nominal vs. Actual R Value

Taped Sheathing Air Barrier

New England Region Modular PassiveHaus: 0.7 ACH 50
Arlington Duplex Retrofit

Exterior Retrofit Complications