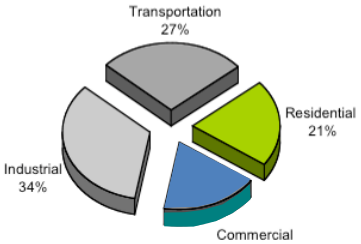
Kohta Ueno

Deep Energy Retrofits: Building America Lessons from the Field

EEBA 2010 EXCELLENCE IN BUILDING CONFERENCE & EXPO
OCTOBER 12-14, 2010 | PORTLAND, OR

Building Energy Use

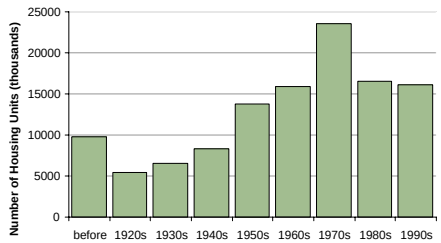
Primary Energy Consumption by Sector, 2001



Source: EIA, Annual Energy Review, 2001 data: www.eia.doe.gov/emeu/aer

Existing Housing Stock

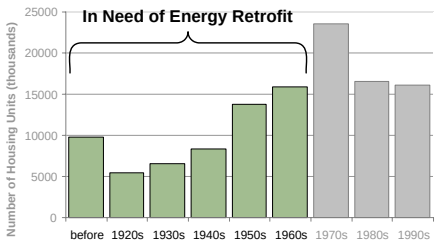
Age of US Housing Stock (all unit types)



Source: US Census Bureau, Annual Housing Survey: http://www.census.gov/hhes/www/housing/ahs/ahs.html

Existing Housing Stock

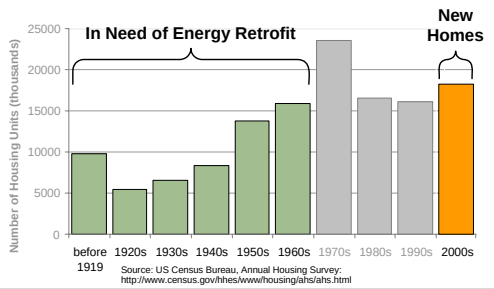
Age of US Housing Stock (all unit types)



Source: US Census Bureau, Annual Housing Survey: http://www.census.gov/hhes/www/housing/ahs/ahs.html

Existing Housing Stock

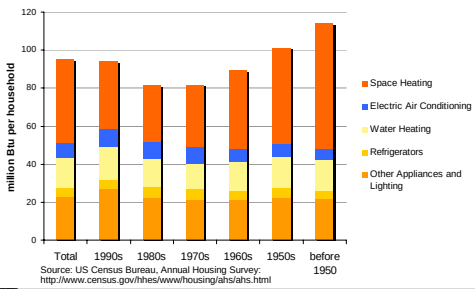
Age of US Housing Stock (all unit types)



Source: US Census Bureau, Annual Housing Survey: http://www.census.gov/hhes/www/housing/ahs/ahs.html

How Old and New Houses Use

Total Btu Consumption per Household, 2001



Source: US Census Bureau, Annual Housing Survey: http://www.census.gov/hhes/www/housing/ahs/ahs.html

Mechanical Retrofit

- After enclosure upgrade
  - Much smaller and quieter systems can be chosen
- Air-based can be replaced with hydronic
- Steam-based can be replaced hot water
- Low-temperature (more efficient) systems can be used
- For ventilations load add HRV
- Variable speed fans and CO_2 controls

Enclosure Retrofit

- Important target for many buildings
  - Insulation
    - Walls
    - Roof
    - Foundations
  - Windows
  - Airtightness
- Prioritize by Ease and Impact

Deep Energy Retrofits

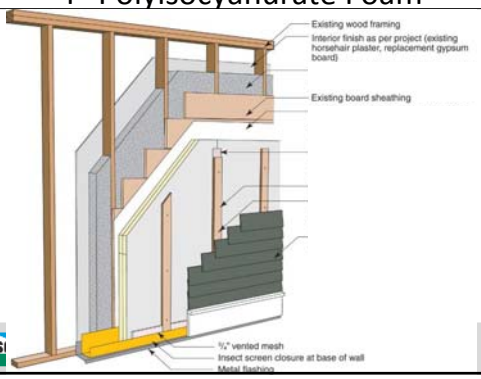
- Significant upgrades are incrementally less expensive
  - Small upgrades very cost effective, but small (10-25% reductions)
  - mid-range upgrades (15-50%) usually really expensive per energy saved
- Deep retrofits (>50%) secure buildings future
  - Allow for new styles, use, etc.
  - Leap frog current housing

Deep Energy Retrofits

- Beyond weatherization retrofits—e.g., R-40 walls, triple glazing, airtightness upgrades
- Cold climate case studies

Walls

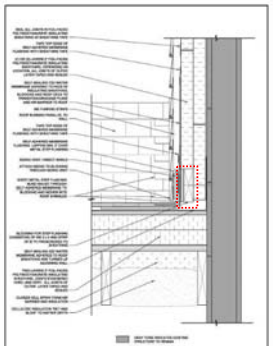
4” Polyisocyanurate Foam



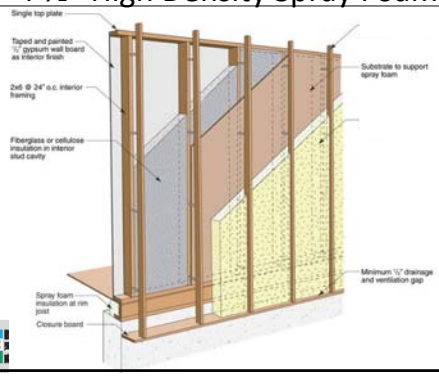
4” Polyisocyanurate Foam

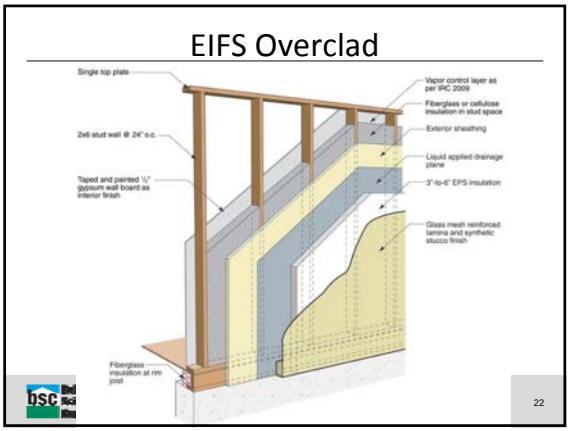
4” Polyisocyanurate Foam

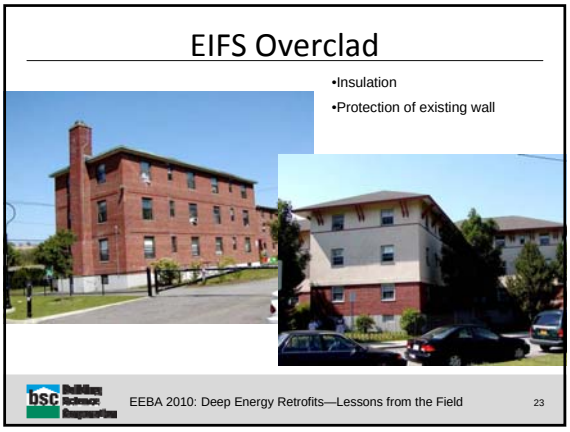
Exterior Retrofit Complications

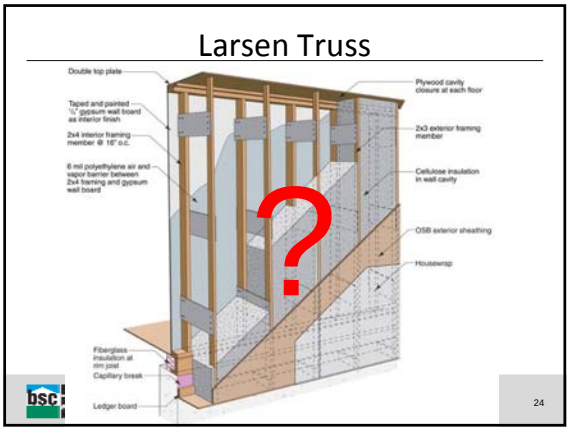


4-½” High Density Spray Foam

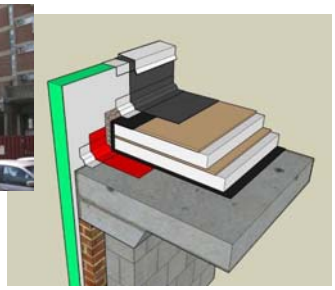



EIFS Overclad
Single top plate
2x6 stud wall @ 24" o.c.
Taped and painted ½" gypsum wall board as interior finish
Fiberglass insulation at rim joist
Vapor control layer as per IRC 2009
Fiberglass or cellulose insulation in stud space
Exterior sheathing
Liquid applied drainage plane
3"-to-6" EPS insulation
Glass mesh reinforced lamina and synthetic stucco finish
22


EIFS Overclad
•Insulation
•Protection of existing wall
EEBA 2010: Deep Energy Retrofits—Lessons from the Field
23


Larsen Truss
Double top plate
Taped and painted ½" gypsum wall board as interior finish
2x4 interior framing member @ 16" o.c.
6 mil polyethylene air and vapor barrier between 2x4 framing and gypsum wall board
Fiberglass insulation at rim joist
Capillary break
Ledger board
Plywood cavity closure at each floor
2x3 exterior framing member
Cellulose insulation in wall cavity
OSB exterior sheathing
Housewrap
?
24

Metal Panel Overclad



Metal Panel Overclad

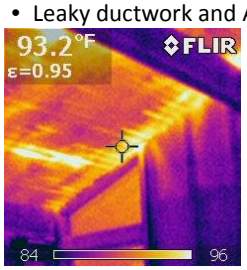
Roofs

Fully Ventilated Attics

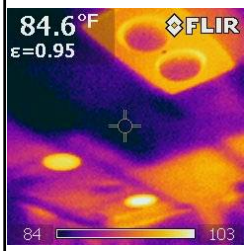
- Can re-roof whenever, with whatever
- Deal with moisture, then add insulation
  - Rain leaks, air leaks
- If possible, keep ventilated attic
  - Inspect ceiling plane, plug all holes with caulking and foam
  - Consider 1” of spray foam air barrier
  - Blow in minimum R60 cellulose, R75-R100 sensible

Why an Unvented Roof?

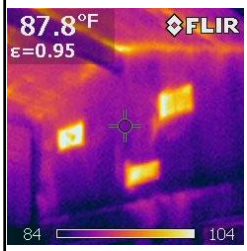
- Difficult air barrier to retrofit @ ceiling plane?
- Leaky ductwork and AHU in attic?



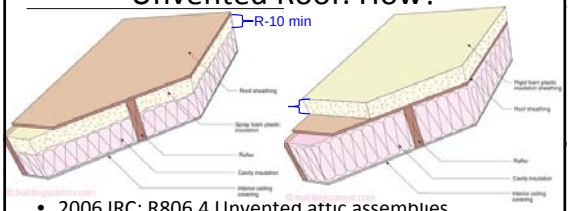
Why an Unvented Roof?



Why an Unvented Roof?



Unvented Roof: How?



- 2006 IRC: R806.4 Unvented attic assemblies
- Minimum R-value of "air impermeable insulation"
- Zone 4C (coastal OR): R-10 minimum (2" XPS)
- Nail base needed with rigid foam on roof deck

Windows

Water Control: Pan Flashings

•Deep energy retrofits (addition of insulation at existing wall) can make the wall more vulnerable to water leakage

•Previously "survivable" leaks may no longer be able to dry out.

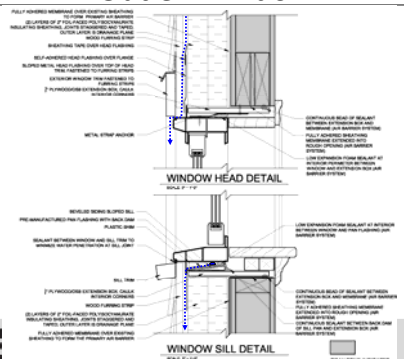
Retrofitting "Superwindows"

U=0.25 to ~0.18 for triple glazed + low E films + Krypton fill gas + warm edge spacers

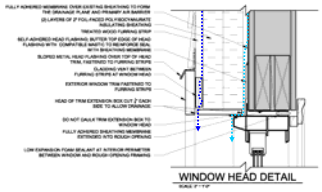
Comparison U=0.35 double glazed, low E, fill gas (?)

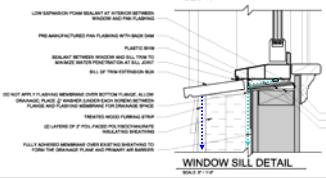
"Innie" and "Outie" Windows

"Outie" Window



"Innie" Window





Recommend placing drainage plane at window location (whichever method you use—innie or outie)!

"Innie" vs. "Outie" Windows

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

"Innie" vs. "Outie" Windows

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

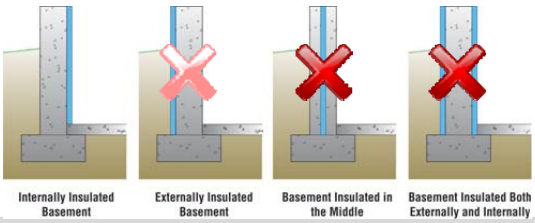
EEBA 2010: Deep Energy Retrofits—Lessons from the Field 43

Foundations

EEBA 2010: Deep Energy Retrofits—Lessons from the Field 44

Insulation Location Choices

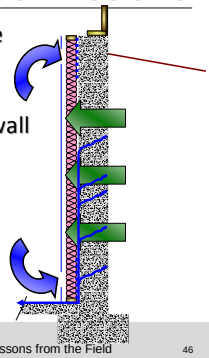
- Retrofits: interior insulation is often the only available option



EEBA 2010: Deep Energy Retrofits—Lessons from the Field 45

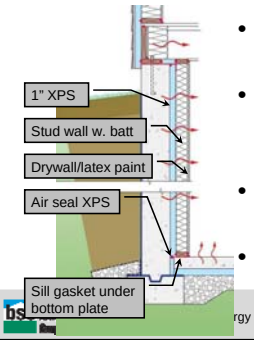
Basement Insulation Problems

- Wintertime interior moisture condensation (like above-grade walls)
- Condensation at bottom of wall (thermal lag of soil)
- Lack of drying of assembly (moisture from concrete and soil); soil is at 100% RH
- Liquid water through wall



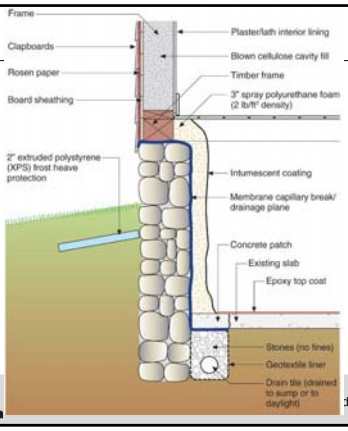
EEBA 2010: Deep Energy Retrofits—Lessons from the Field 46

Recommended Wall Assembly



- Wintertime condensation controlled
- Summertime (bottom of wall) condensation controlled
- Concrete can dry through XPS at a safe rate
- XPS is moisture tolerant

rgy Retrofits—Lessons from the Field 47

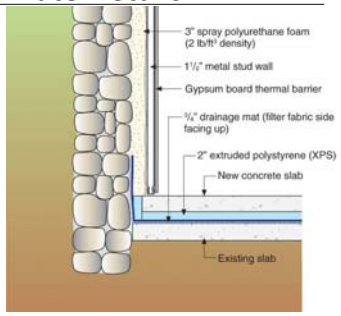


48

Interior Rubble Retrofit

Alternate Details

- Insulated slab on top of existing slab
- No membrane up wall surface
- Wet vs. dry basement?
- Light gauge steel framing interior wall



Air Barriers

Retrofitting Exterior Air Barriers

Bedford, MA
"Farmhouse"

6.2 ACH 50

No secondary air barrier (housewrap w. connections); mediocre roof-wall connections

Arlington, MA
"Duplex"

5.0 ACH 50

Basement compartmentalized? (1000 CFM 50 vs. 2129 CFM 50 total)

Concord, MA
"Four Square"

3.1 ACH 50

Mechanical penetrations, porch attachments, replacement sash windows

Retrofitting Exterior Air Barriers

St. Agatha, ON

~1 ACH 50

Spray foam on exterior; all windows well air sealed; casement/ awning typical

Belmont, MA

0.9 ACH 50

Rigid foam as air barrier, "chainsaw" retrofit of roof overhangs/eaves, meticulous air barrier, blower door tests in progress

- Roof-wall connections
- Wall-foundation connections
- Wall-window connections
- Structural attachments
- Mechanical system penetrations
- Thermal bridges

Mechanicals

Mini Splits

Mini-split non-ducted head

Mini-split short ducted system

Mini-split outdoor unit

- Both heating & cooling
- Multi-splits (single outdoor unit)
- Systems with SEER=26 and HSPF=11 available

Mini-Splits Heating/Cooling in Cold Climate

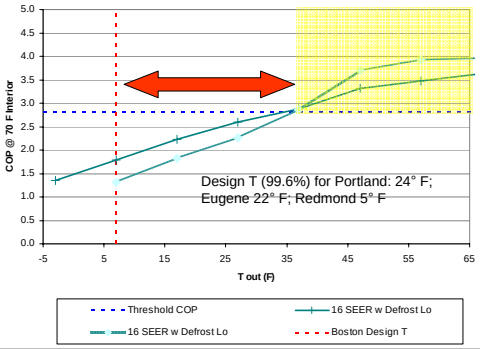
- 1818 sf house, solar-oriented, superinsulated (12" spray foam walls, R-80 roof), triple glazed windows, very airtight
- Central Massachusetts location
- Net zero performance

- Provides for both heating & cooling; 11,000 BTU heating load
- Installed costs in the 1,818 square foot "Farmhouse" was $6,850
- Two 9,000 BTU heads upstairs, One 12,000 BTU head downstairs
- Electric heater back up, no heat production below zero degrees outside

Mitsubishi SEZ Ducted Indoor units

- Provides for both heating and cooling, 17,000 BTU peak heating load
- Installed costs in the 4 BR 2,612 square foot "Carlisle" model was $7,600
- One 15,000 BTU heads upstairs, One 18,000 BTU head downstairs
- 20,000 BTU gas fireplace as back up heating system

Heat Pump Behavior



Questions?

Building AMERICA SM
U.S. Department of Energy