Introduction

Building Energy Use

Existing Housing Stock

Existing Housing Stock
How Old and New Houses Use

Total Btu Consumption per Household, 2001

<table>
<thead>
<tr>
<th>Year</th>
<th>Space Heating</th>
<th>Electric Air Conditioning</th>
<th>Water Heating</th>
<th>Refrigerators</th>
<th>Other Appliances and Lighting</th>
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</thead>
<tbody>
<tr>
<td>1990s</td>
<td>150</td>
<td>120</td>
<td>100</td>
<td>50</td>
<td>20</td>
</tr>
<tr>
<td>1980s</td>
<td>120</td>
<td>110</td>
<td>80</td>
<td>40</td>
<td>15</td>
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<tr>
<td>1970s</td>
<td>100</td>
<td>90</td>
<td>60</td>
<td>30</td>
<td>10</td>
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<tr>
<td>1960s</td>
<td>80</td>
<td>70</td>
<td>40</td>
<td>20</td>
<td>5</td>
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<tr>
<td>1950s</td>
<td>60</td>
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<td>20</td>
<td>10</td>
<td>2</td>
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<tr>
<td>Before 1950</td>
<td>40</td>
<td>30</td>
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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

National Grid DER Pilot Program

- Residential deep energy retrofit (DER) pilot program
- Incentives ~$35 to $60 K
- R-60 roof, R-40 walls, R-20 bsmt wall, U≤0.2 windows
- Eight completed projects
- 27 current active projects
- BSC provides technical guidance for program

Delta T Comparisons

- ΔT is what drives heat loss/gain—therefore R values, energy paybacks, etc.
- “Dominant load” (heating vs. cooling dominated climates)
- Dominant ΔT much higher in cold climates (New England)—higher R value targets

Las Vegas ≠ New England
## R-Value Targets

<table>
<thead>
<tr>
<th>Climate Zone</th>
<th>Wall</th>
<th>Yenid</th>
<th>Pitched Roof</th>
<th>Flat Roof</th>
<th>Basement Floor</th>
<th>Exposed Floor</th>
<th>Stab or Edge</th>
<th>Windows (u-value/FHZ)</th>
<th>Subslab Stabilized</th>
<th>Notes</th>
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<tr>
<td>1</td>
<td>10</td>
<td>40</td>
<td>35</td>
<td>5</td>
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<td>10</td>
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<tr>
<td>2</td>
<td>15</td>
<td>50</td>
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<td>10</td>
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<td>40</td>
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<tr>
<td>5</td>
<td>30</td>
<td>50</td>
<td>40</td>
<td>15</td>
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<tr>
<td>6</td>
<td>35</td>
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<td>40</td>
<td>15</td>
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<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>none</td>
</tr>
</tbody>
</table>

- "True" R value: R-13 2x4 wall = R-8; R-19 2x6 wall = R-12
- Estimated targets—will vary with local construction costs, energy costs, client targets

Source: RR-1005: High R-Value Enclosures for High Performance Residential Buildings in All Climate Zones

### Airtightness targets

- Zones 1-3: 0.25 CFM 50 per sf enclosure area
- Zones 4-6: 0.20 CFM 50 per sf enclosure area
- Zones 7-8: 0.15 CFM 50 per sf enclosure area

Source: RR-1005: High R-Value Enclosures for High Performance Residential Buildings in All Climate Zones

### Construction Differences

But this talk is about New England deep energy retrofits…

### Walls

### Exterior Insulation Retrofits

- Going beyond nominal R-13/R-19 walls = thicker walls
- 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)
  - Interior stairwells (code minimum widths)
4” Polyisocyanurate Foam

Foam Sheathing Cladding Attachment

250 lbs/113 kg load (7.8 psf): <0.003” deflection
Wood siding ~2 psf
Fiber cement 2-3 psf
Stucco 8-10 psf

Image c/o Petersen Engineering

Exterior Retrofit Complications

4-½” High Density Spray Foam
**EIFS Overclad**

- Insulation
- Protection of existing wall
- Aesthetic improvement?

**Metal Panel Overclad**

**Roofs**

**Fully Ventilated Attics**

- Can re-shingle 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

**Fully Ventilated Attics**

**Fully Ventilated Attics**
Why an Unvented Roof?

- Difficult air barrier to retrofit @ ceiling plane?
- Leaky ductwork and AHU in attic?
- More space (dormers, bedrooms in attic)?

Unvented Roof: How?

- 2006 IRC: R806.4 Unvented attic assemblies
- Minimum R-value of “air impermeable insulation”
- Zone 2B/3B + tile roof: none required
- Nail base needed with rigid foam on roof deck

Windows

- 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

“Innie” vs. “Outie” Windows

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

• “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)

“Outie” Window Installation Options

Foundations
### Basement Insulation Location

- **Location**: Basement

#### Insulation Location Choices

- **Retrofits**: interior insulation is often the only available option

#### Insulation Location 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

#### Recommended Wall Assembly

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

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**Basement Insulation Location**

- **Location**: Basement

- **4.6 ACH50; 2129 CFM 50 total; 1100 CFM 50 through floor**
- **8.5 ACH50; 3590 CFM 50 total; 1740 CFM 50 through floor**
Interior Rubble Retrofit

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

Alternate Details

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

Spray foam basement insulation

- Open cell
  - Climate specific
- Closed cell

Spray Foam “Bathtub”

- Closed cell
- Open cell – Climate specific

Retrofitting Exterior Air Barriers

<table>
<thead>
<tr>
<th>Location</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bedford, MA</td>
<td>“Farmhouse”</td>
</tr>
<tr>
<td>6.2 ACH 50</td>
<td>No secondary air barrier (housewrap w. connections); mediocre roof-wall connections</td>
</tr>
<tr>
<td>Arlington, MA</td>
<td>“Duplex”</td>
</tr>
<tr>
<td>5.0 ACH 50</td>
<td>Basement compartmentalized? (1000 CFM 50 vs. 2129 CFM 50 total)</td>
</tr>
<tr>
<td>Jamaica Plain, MA</td>
<td>Vented space under existing slate roof; spray foam; All spray foam basement (“bathtub”); No clear failure points</td>
</tr>
</tbody>
</table>
Retrofitting Exterior Air Barriers

- St. Agatha, ON: ~1 ACH 50 spray foam on exterior; all windows well air sealed; casement/awning typical
- Belmont, MA: 0.7 ACH 50 rigid foam as air barrier, “chainsaw” retrofit of roof overhangs/leaves, meticulous air barrier; lower door tests in progress
- Northampton, MA: Taped ZIP wall air barrier layer roof & walls; spray foam basement; 40% new construction

Other projects in 1.5 ACH 50 range; ~3-5 ACH 50 outliers, under 1 as well
- Roof-wall connections
- Roof geometries
- Wall-foundation connections
- Window air leakage
- Wall-window connections
- Porch/deck attachments
- Mechanical system penetrations
- Rigid air control layer on walls

Air Barriers and Brick Buildings

- Pre-retrofit test
- Brick (2-wythe); front and rear exposed, party walls
- Vinyl replacement windows
- Whole-building test
  - 11.7 ACH 50
  - 0.9 CFM 50/sf enclosure
- Roof, chimneys, window-wall interfaces?

Mechanicals

- Range of approaches
- Often similar to new construction
- After enclosure upgrade
  - Much smaller and quieter systems can be chosen
- Air-based can be replaced with hydronic
- Low-temperature (more efficient) systems can be used (e.g., steam → hot water)
- For ventilation load add HRV (or ERV)
**Heating: Steam to Hydronic**

- Removed hazardous material
- Freed valuable floor space
- More even control
- Efficient, sealed combustion
- Provided option for more efficient water heater

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**Heating: Steam to Hydronic**

Manifold Distribution – home run to every radiator

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**Heating: Steam to Hydronic**

PEX tubing: Minimally destructive distribution

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**Heating: Steam to Hydronic**

Thermostatic Radiator Valves (TRVs): every radiator its own zone

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**Combustion Safety**

- Backdrafting risk in tighter houses
- Combustion air should be drawn from outside ("sealed combustion")

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**Sealed Combustion**

Retrofit atmospherically vented?

- Maybe boilers
- Not water heaters
- Is it worth it?
Mini-Splits

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

Mini-Split Heat Pumps

- Single point heating per floor can keep rooms close to setpoint (~5-7°F)
- Deep heating setbacks cause greater differences
- Leaving doors closed increases temperature differences
- Deep setbacks result in long runtimes for mini split heat pumps
- “Acceptable sizing” data inconclusive, but other practitioners in colder climates have hard data
- Effective trade-off for superinsulated enclosure

HRV Induced Flow

- AHU running, HRV not running → unintended airflow
- Overall air leakage + duct leakage issues
- Need motorized damper in addition to backdraft dampers

Site and Source Energy

- Site-source conversion changes based on location/grid, time of day, season
- Site-source number has change of improving with more renewable power
EEBA Course Description

- **Short Description:**
  
  A New England utility company has implemented a deep energy retrofit pilot program, with the goal of energy savings of over 50%. Several projects have been completed, with several more in progress and under construction. This session will cover measures implemented, savings achieved, and lessons learned in this program.

- **Learning Objectives:**
  
  - Understand some of the benefits and risks of exterior wall retrofit insulation systems.
  - Understand the pros and cons of including the basement within the conditioned space.
  - Understand some of the challenges involved in retrofitting exterior air barriers to existing buildings.
  - Understand the magnitude of savings achievable with these types of deep energy retrofits.

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**Questions?**

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