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Building AMERICA
U.S. Department of Energy
Research Toward Zero Energy Homes

Low-Energy Buildings Intro and Retrofits

John Straube


www.buildingscience.com




What Do We Want To Do?

- Safe**
- Healthy**
- Comfortable**
- Durable**
- Affordable**
- Environmentally Responsible**

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Existing US Housing


- **Total Housing Units in 2001 (millions):**

| | |
|----------------------------|------|
| Single-Family Homes | 73.7 |
| Apartments (all buildings) | 26.5 |
| Mobile Homes | 6.8 |
| Constructed since 2001 | 10 |

Approx Existing Units: 115 million units¹

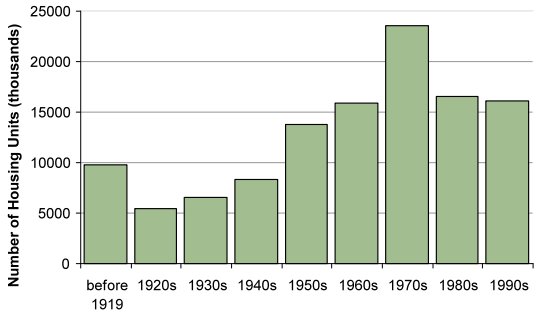
1. Energy Information Administration, Residential Energy Consumption Survey, 2001 data: www.eia.doe.gov/emeu/recs
 2. EIA, Annual Energy Review, 2001 data: www.eia.doe.gov/emeu/aer

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Existing Housing Stock

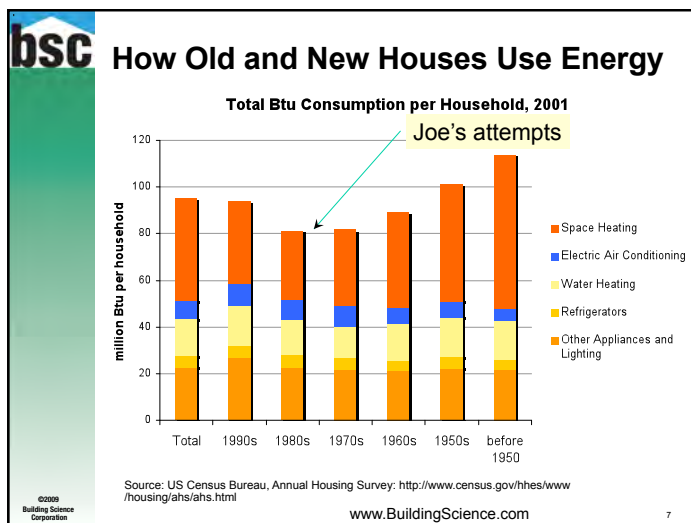
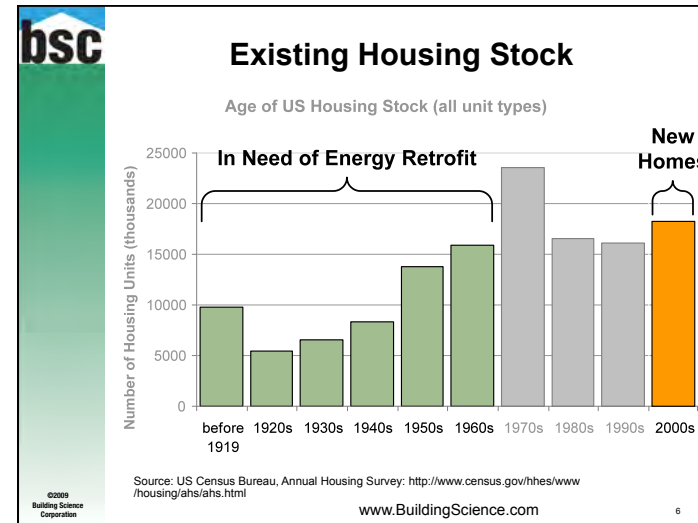
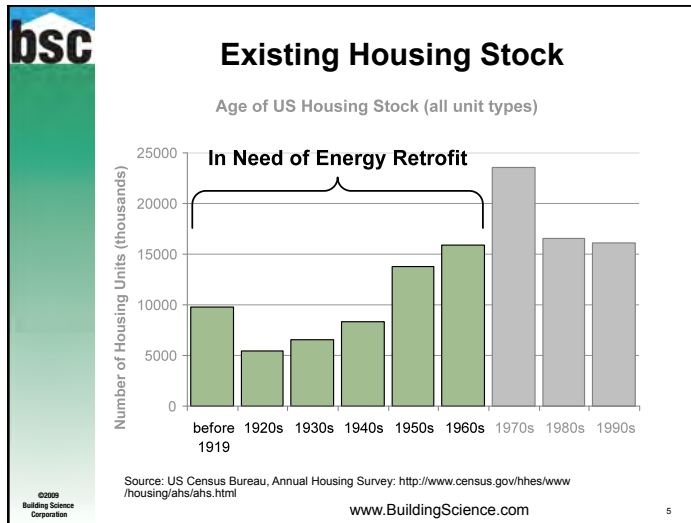
Age of US Housing Stock (all unit types)



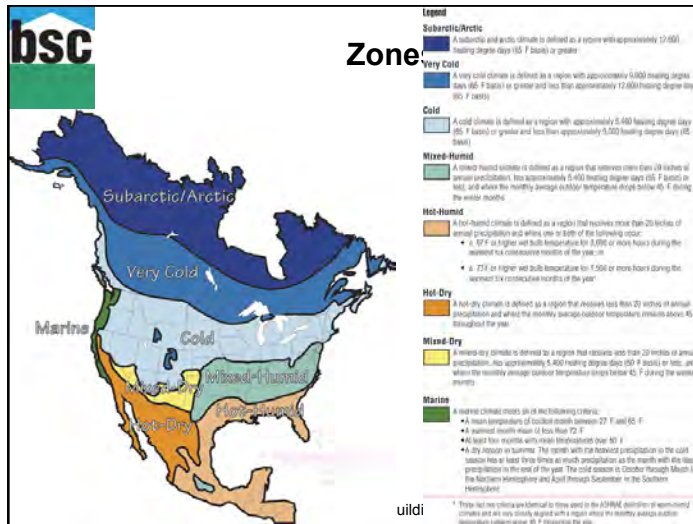
| Decade | Number of Housing Units (thousands) |
|-------------|-------------------------------------|
| before 1919 | 10,000 |
| 1920s | 5,000 |
| 1930s | 6,500 |
| 1940s | 8,000 |
| 1950s | 13,500 |
| 1960s | 16,000 |
| 1970s | 23,000 |
| 1980s | 16,500 |
| 1990s | 16,000 |

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

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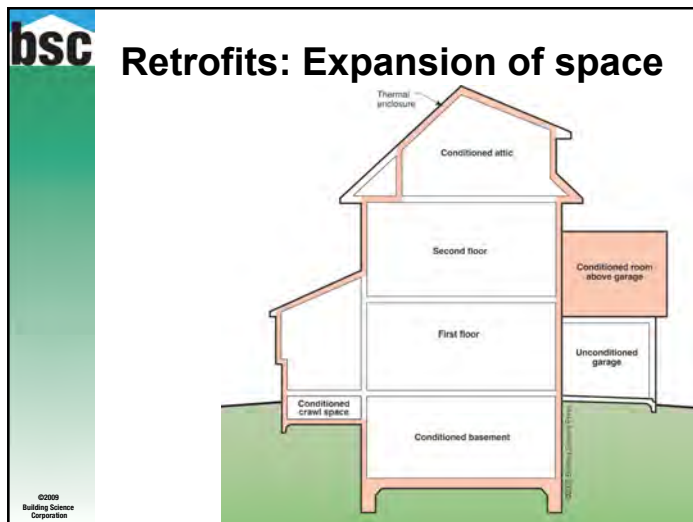
- Residential, single family**
1. Comfortable, durable, healthy, safe
 2. Insulate wall, roof basement, airtighten
 3. Limit window-to-wall ratio (WWR) to <30%
 4. Control ventilation, use energy recovery ventilation
 5. Upgrade windows (control SHGC and R-value)
 6. Use efficient lighting, right-sized
 7. Use efficient appliances
 8. Use efficient heating and domestic hotwater equip.
 9. Consider source of energy
 10. Add renewables to push toward zero
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The Whole Building Approach

- Performance Issues driving Retrofit:
 - Comfort
 - More utility
 - Health concerns
 - Durability / repair needs
 - Operating Costs
 - Energy Efficiency & Environment

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Retrofit: How to reduce energy?

BSI-014

- Changing mechanical systems is least invasive
 - Lifespan is moderate, say (20 yrs)
 - 10% eff improvement = 10% operating savings = easy
- Lighting and ventilation
 - Change is easy at any time
 - Lighting and controls payback quickly
- Enclosures
 - Windows last 25-50 yrs
 - Insulation last 100+ yrs
 - Cladding lasts 35-200+ years
- **MUST** have clear idea of enclosure upgrades **before** deciding on mechanical!


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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 hotwater**
- **E.g. Low-temperature (more efficient) systems can be used**
- **For ventilations load add HRV**
- **Variable speed fans and CO₂ controls**


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Enclosure Retrofit

- **Important target for most houses**
 - Airtightness
 - Windows
 - Insulation
 - Roof
 - Walls
 - Basement
 - Slabs
- **Prioritize by Ease and Impact**

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Deep Retrofit

Simple upgrades have great paybacks but have little impact
 Small upgrades very cost effective, but small (10-25% reductions)

Mid-range upgrades (15-50%)
 usually quite expensive per energy saved

Deep retrofits (>50%) secure buildings future
 Cost a lot, save a lot.
 But ... allow for new styles, repair/replace, more use, etc.
 Leap frog current housing

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Basements

- Easy to retrofit and improve from the interior
- Ceiling height is the big restriction for slab solutions

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Labels in diagram:

- Isocyanate spray foam insulation extended into band joist area
- Existing foundation wall
- Icyene spray foam insulation
- 2x3 24" o.c. wood stud wall attached to floor and floor joists
- 1/2" gypsum wall board, hold up from floor 1/2" minimum
- Capillary break
- New 3" concrete slab
- 2" XPS rigid foam insulation (unfaced) tape all joints
- 1" Erika drain (entire slab)
- Existing concrete slab

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Labels in diagram:

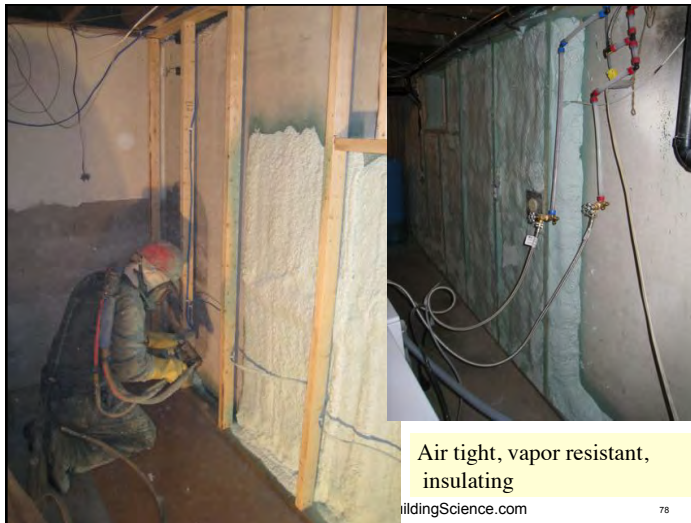
- Polyisocyanurate limits moisture flow from the interior during winter
- Exposed portion of foundation wall able to dry to the exterior
- Sprayed polyurethane foam limits interior moisture migration
- Drainage mat limits interior moisture migration from the existing slab and soil

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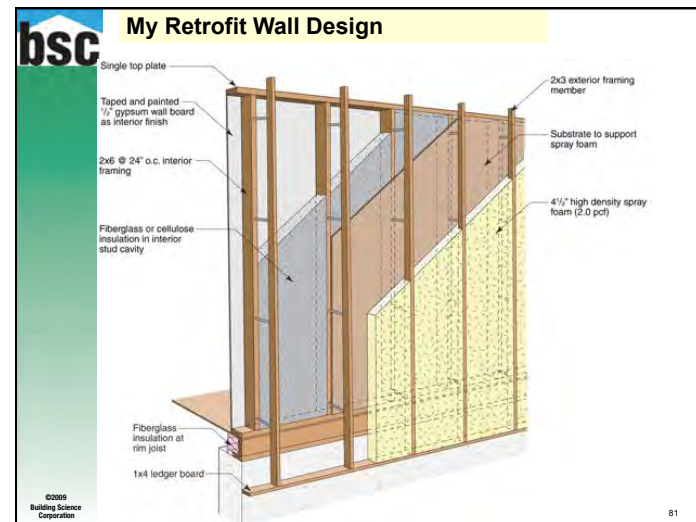


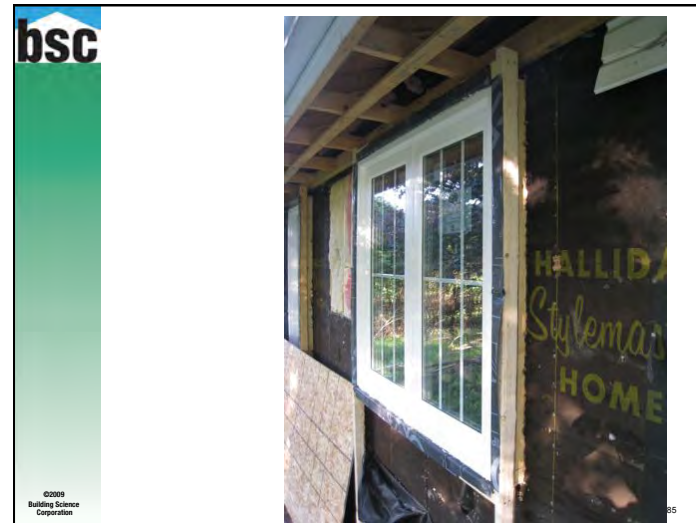
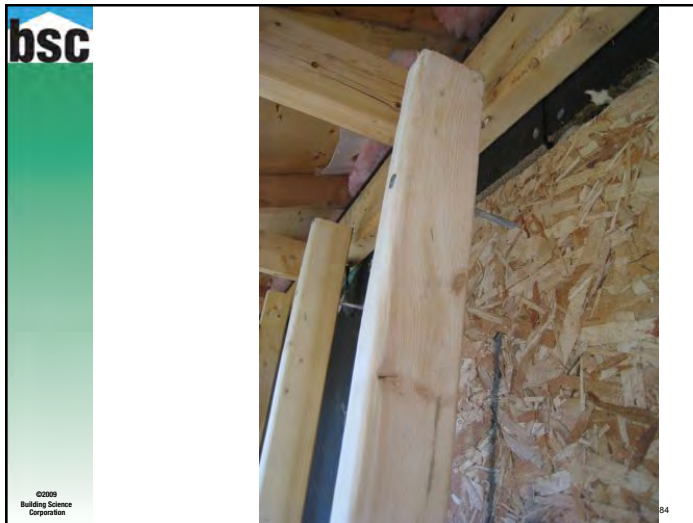
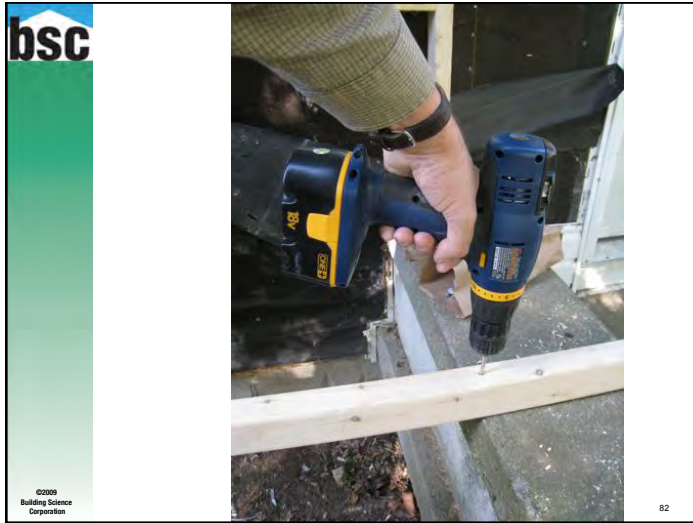
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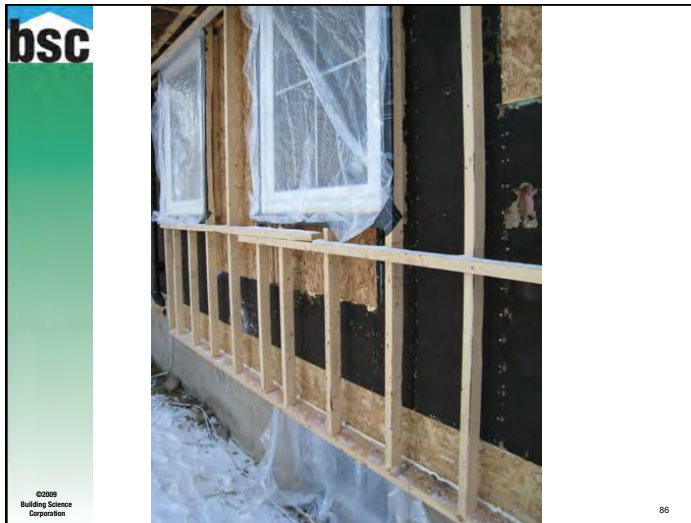
Above grade walls

- **Interior retrofit** limits improvements to airtightness, rain control, thermal bridge
- **Exterior retrofit** allows excellent improvements and increased durability
- **Windows** should be done at the same time! Risky
- **Installation cost \$200+/-** so get good windows, eg vinyl triple glazed for \$30/sf

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The thermal resistance of the wall assembly is made up of the blown cellulose cavity insulation and the two layers of 2-inch rigid polyisocyanurate insulating sheathing

New windows with low-E squared glazing maintain the thermal continuity of the wall

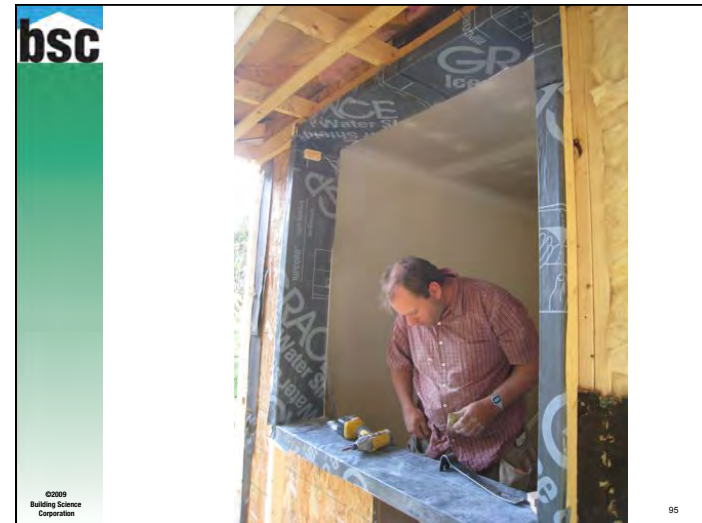
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- Important choice!
- Need better rain control
- Improved R-value of course
 - Triple-glazing becoming affordable

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 Four small photographs showing the process of installing a window. The first shows a window being lowered into a frame. The second shows a worker adjusting the window. The third shows a worker sealing the window. The fourth shows a worker finishing the installation.

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 Photos courtesy of Dan Morrison, *Fine Homebuilding Magazine*
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- **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

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Conditioned Attics

- **Needs a good new roof**
 - Top quality underlayment needed
- **Unvented roofs best for complex shapes**
 - Air sealing is critical
- **Venting if you can easily achieve this**
 - Ensure real venting!

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Sloped Wood Roofs

- **Usually require re-roofing and structural repair**
- **Deal with moisture, then add insulation**
- **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.
- **If cathedral, insulate AND airtighten**
 - Insulation on exterior is a benefit
 - airtighten

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hsc **Conditioned attics**

The inferior plane of air tightness is provided by the sprayed polyurethane foam

Continuity of the air barrier is maintained at the roof to wall connection by the sprayed polyurethane foam

The draining housewrap provides an interior plane of air tightness.

R65, note air barrier continuity

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Roofing paper

Soft sheathing (optional) membrane lapped over edge of roof sheathing and extending to min. 3" from roof edge

Metal drip edge

1" x 4" sheath board

2" x 10" sub-floors

1/2" x 10" sheath board

2x6 (joint extension scanted to existing framing) cut to match roof angle

Flash on outer layer of sheathing sheathing to fit around existing framing, sealing assembly to be flush with attic deck

Two layers 2" foil-faced polyisocyanurate insulation sheathing, joints staggered horizontally and vertically, all joints of outer layer taped and sealed

1/2" furring strips

Cellulose insulation "top and bottom" to rafter depth

Closed cell spray foam air barrier and insulation

Remove second attic deck board to allow access for spray foam application

Existing ceiling joist continuous over top plate

Existing construction

Gray tone indicates existing structure to remain

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Mechanicals

- **Definitely add mechanical ventilation**
- **Heat recovery now or later**
- **Remove and replace oil burners**
- **Natural gas is cheap and low carbon**
 - Even if it is only cheap for 10 yrs, NG pays
- **If you don't have natural gas**
 - Electricity via heat pumps
 - Heat via biomass boilers

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