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

Low-Energy Buildings Intro and Retrofits

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www.buildingscience.com

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What Do We Want To Do?

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

Existing US Housing

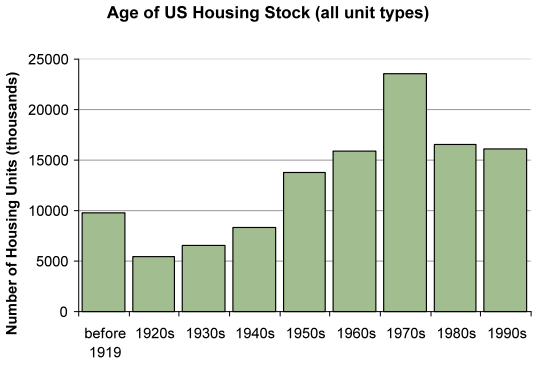
- **Total Housing Units in 2001 (millions):**

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

Approx Existing Units: 115 million units[1]

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

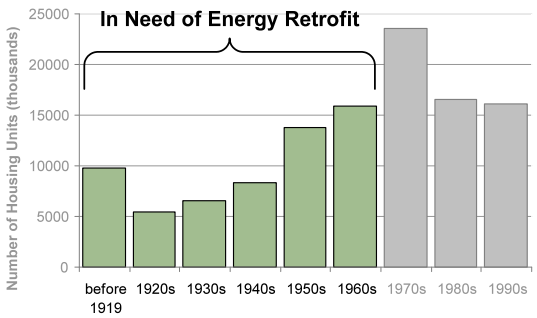
Existing Housing Stock



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)



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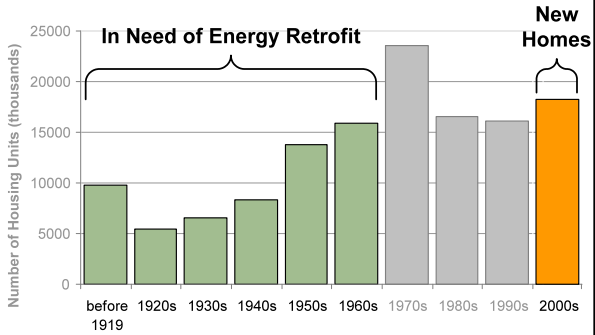

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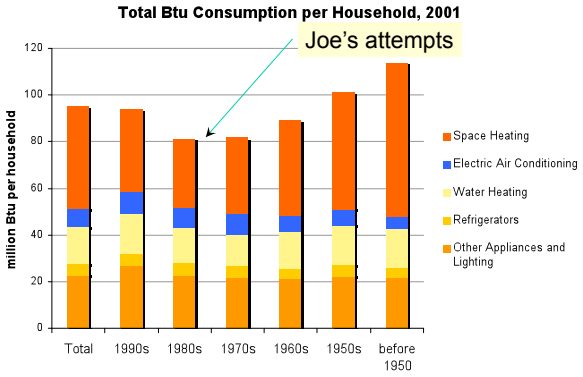
How Old and New Houses Use Energy

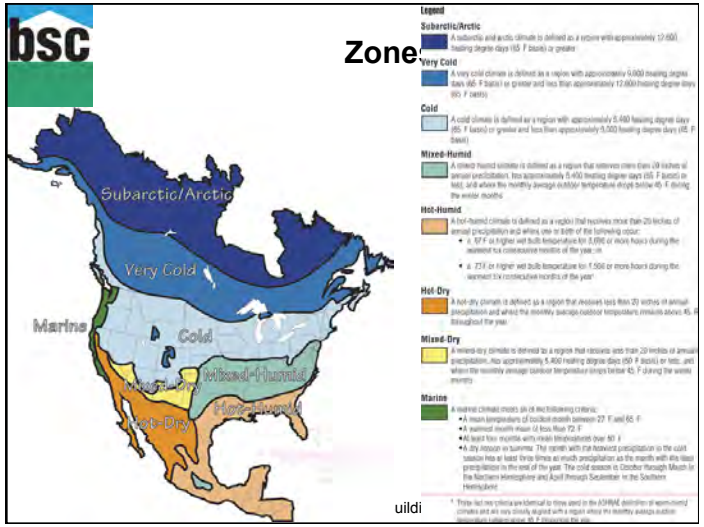
Total Btu Consumption per Household, 2001



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

Residential, single family

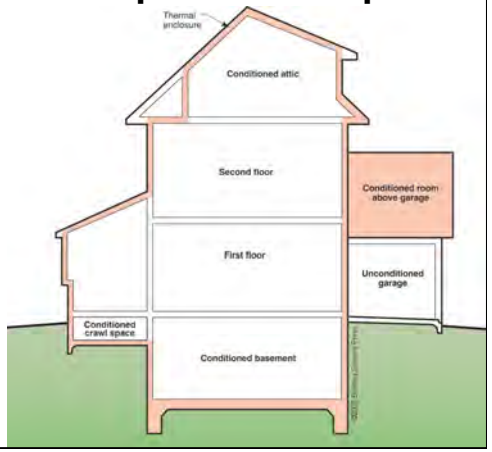
1. Comfortable, durable, healthy, safe
2. Insulate wall, roof basement, airtighten
3. Limit window-to-wall ratio (WWR) to <30%
4. Control ventilation, use energy recovery ventilation
5. Upgrade windows (control SHGC and R-value)
6. Use efficient lighting, right-sized
7. Use efficient appliances
8. Use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



The Whole Building Approach

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

Retrofits: Expansion of space



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!**

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 CO_2 controls**

Enclosure Retrofit

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

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

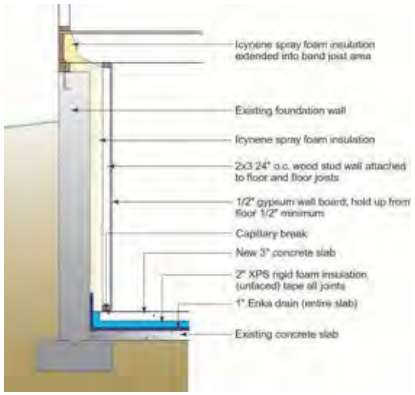
Cost a lot, save a lot.

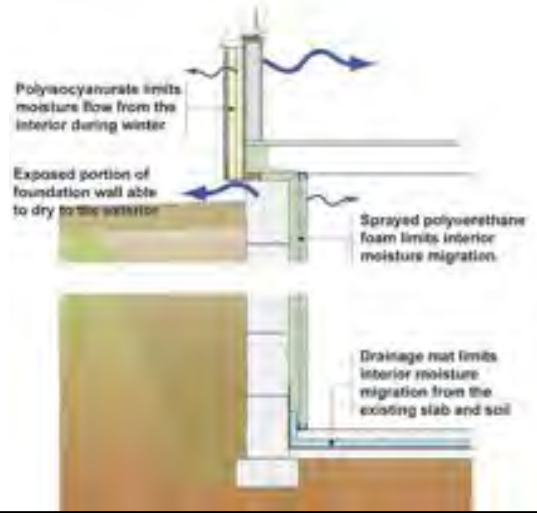
But … allow for new styles, repair/replace, more use, etc.

Leap frog current housing

Basements

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



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Sump pit basin in corner
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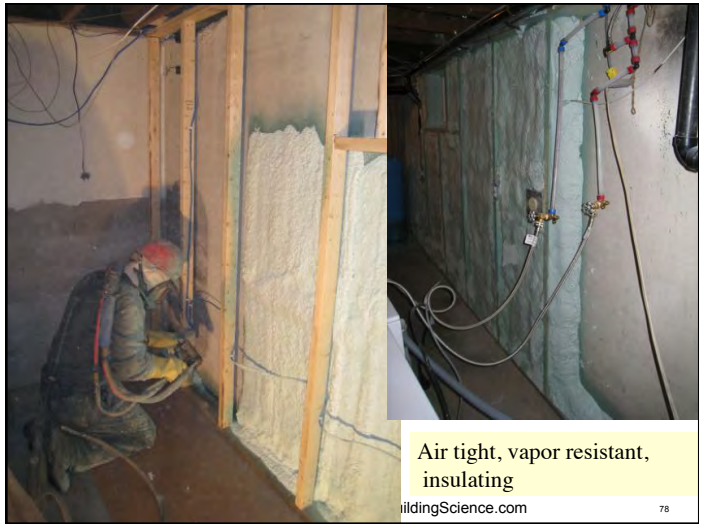
My retrofit


Cap break = peel and stick



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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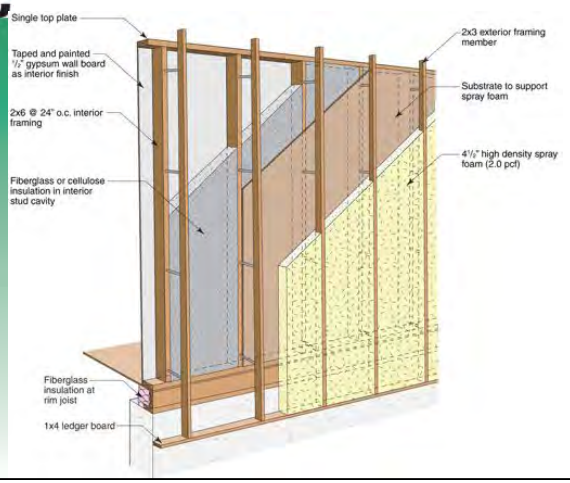
My Retrofit Wall Design



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Retrofit
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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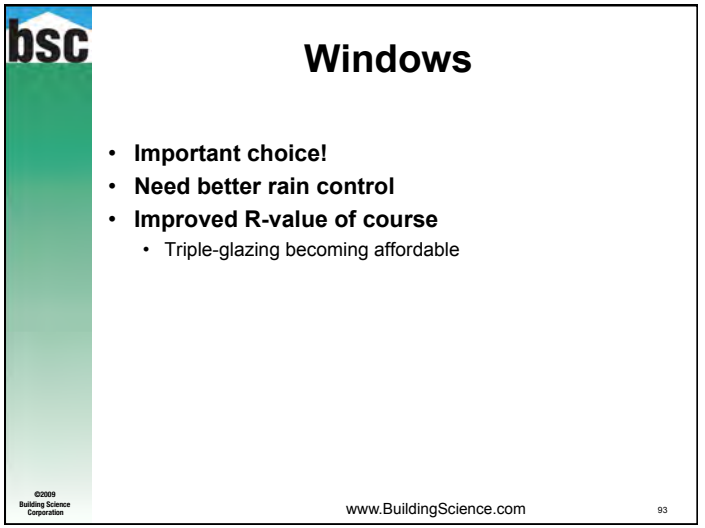
Standard Alternate: 4” PIC= R26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Windows
• Important choice!
• Need better rain control
• Improved R-value of course
• Triple-glazing becoming affordable
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New Windows

Photos courtesy of Dan Morrison, *Fine Homebuilding Magazine*

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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

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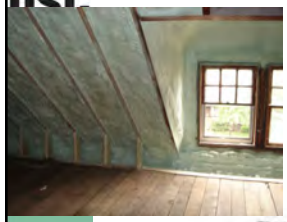
Conditioned Attics

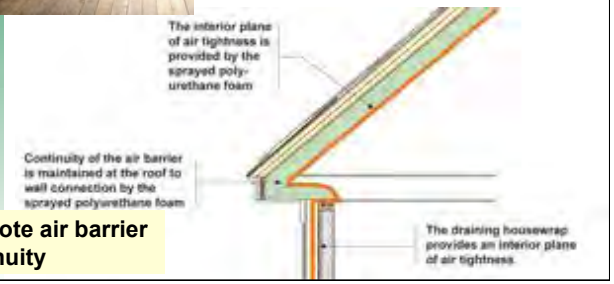
- **Needs a good new roof**
  - Top quality underlayment needed
- **Unvented roofs best for complex shapes**
  - Air sealing is critical
- **Venting if you can easily achieve this**
  - Ensure real venting!

Sloped Wood Roofs

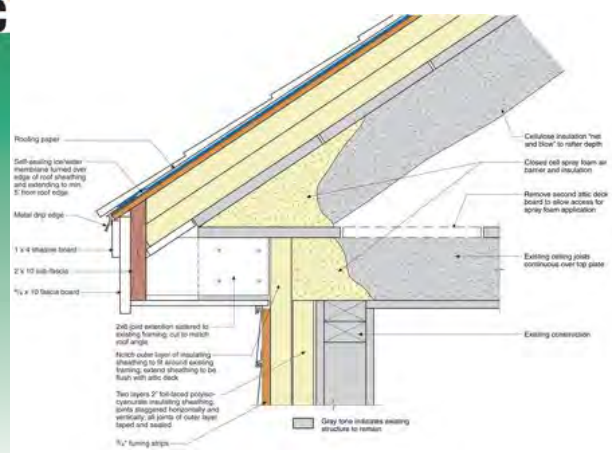
- **Usually require re-roofing and structural repair**
- **Deal with moisture, then add insulation**
- **If possible, keep ventilated attic**
  - Inspect ceiling plane, plug all holes with caulking and foam
  - Consider 1” of spray foam air barrier
  - Blow in minimum R60 cellulose.
- **If cathedral, insulate AND airtighten**
  - Insulation on exterior is a benefit
  - airtighten

Conditioned attics





R65, note air barrier continuity



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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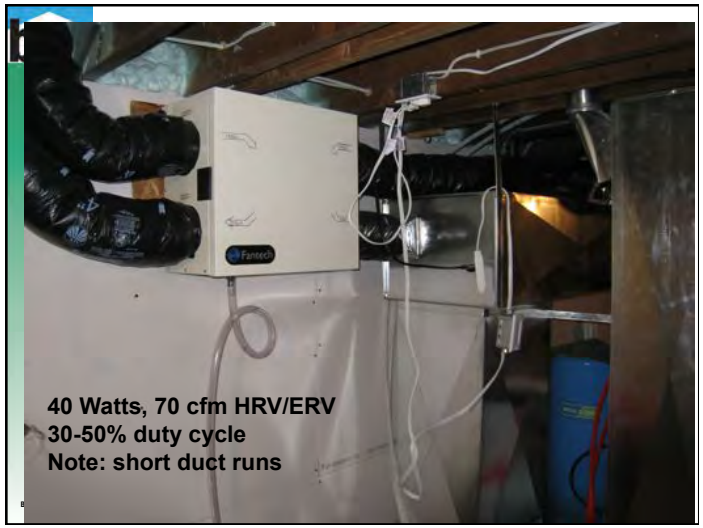
40 Watts, 70 cfm HRV/ERV
30-50% duty cycle
Note: short duct runs