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Four Square Revisited Toward Zero Energy Renovation

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www.buildingscience.com

Better Buildings: Better Business Conference
March 6, 2008 Wisconsin Dells, Wisconsin



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bsc **Assessing the Impact of US Housing**

Background:

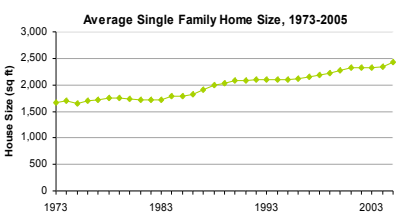
- Total Housing Units in 2001 (millions):**
 - Single-Family Homes (2/3 built prior to 1970) 73.7
 - Apartments (all buildings) 26.5
 - Mobile Homes 6.8
 - 107.0 million units¹**
- Total Residential Energy Use in 2001:**
 - 20,228,107 million Btu²

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

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bsc **Getting Bigger as Time Goes On**

- Average House Size in 1940:** ~1100 sq ft¹
- Average House Size in 1973:** 1660 sq ft²



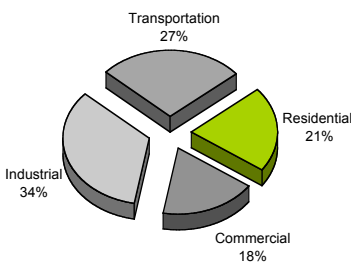
Average House Size in 2005: 2434 sq ft

1. Wilson, Alex and Jessica Boehland "Small is Beautiful", *Journal of Industrial Ecology*, Vol 9, No 1-2, 2005
2. EIA, Annual Energy Review, 2001 data: www.eia.doe.gov/emeu/aer

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bsc **Assessing the Impact of US Housing**

Primary Energy Consumption by Sector, 2001

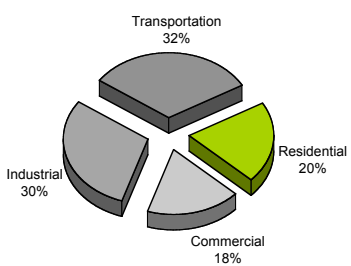


Source: EIA, Annual Energy Review, 2001 data: www.eia.doe.gov/emeu/aer

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bsc **Contribution to Climate Change**

Carbon Dioxide Emissions from Energy Consumption by Sector, 2001

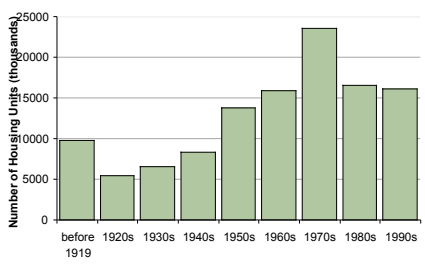


Source: EIA, Annual Energy Review, 2001 data: www.eia.doe.gov/emeu/aer

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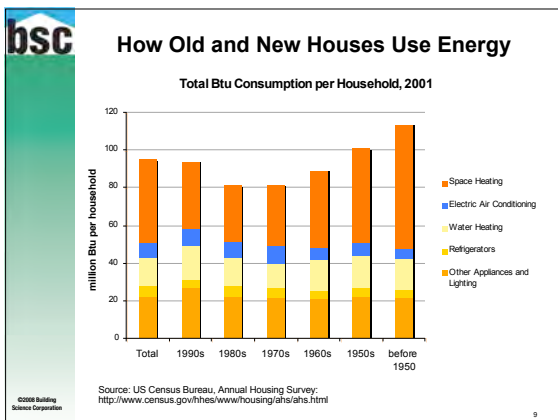
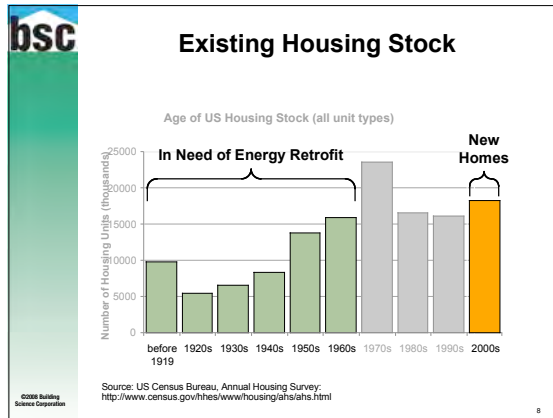
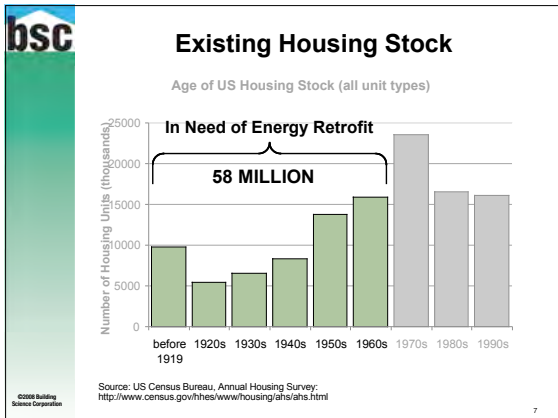
bsc **Existing Housing Stock**

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>

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How a 100 year old house is renewed to last an additional 100 years cost \$100/sq. ft.

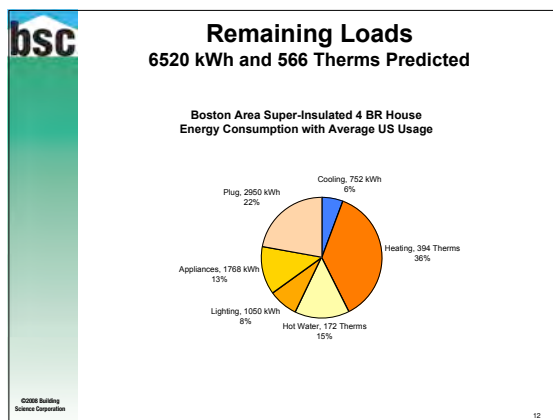
Building Enclosure	BEFORE	CONDITIONED SQ. FT. = 2,000
Air Leakage	10 sq. in. of leakage area per 100 sq. ft. of surface area	
Wall Insulation	Little to none	
Attic Insulation	R-19	
Windows	Single pane glass with storm window	

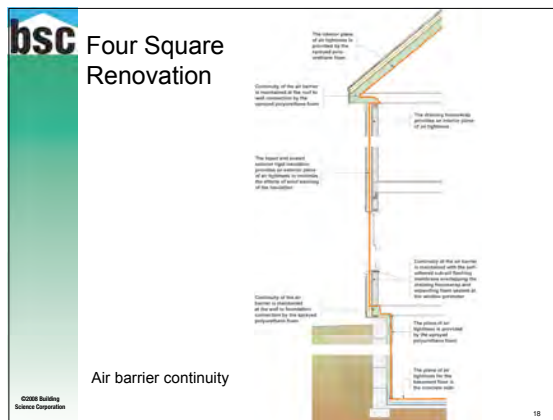
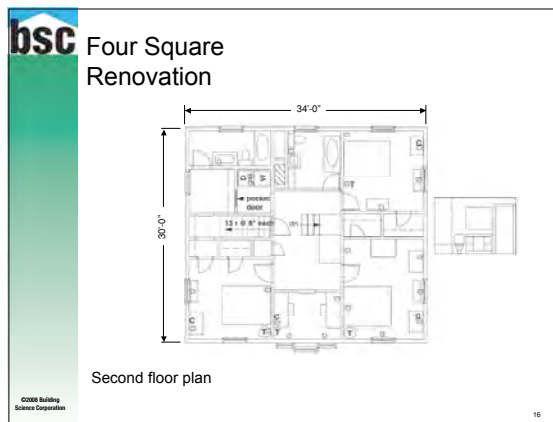
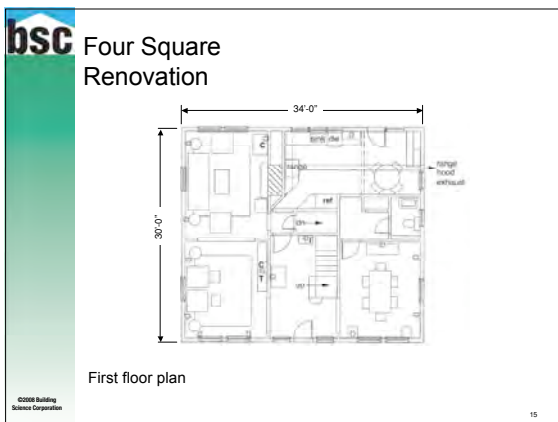
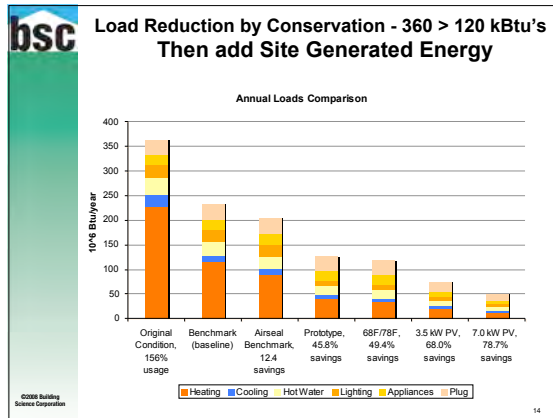
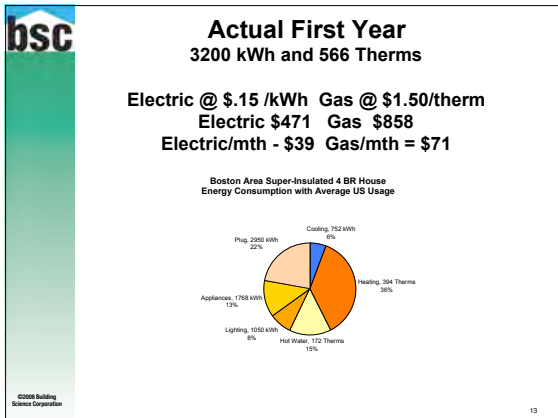
Building Enclosure	AFTER	CONDITIONED SQ. FT. = 3,600
Conditioned Attic	R-39 High Density Spray Foam on sheathing R-21 roof deck insulation – Total Roof R-60	
Walls	R-13 cellulose blown into existing 2x4 walls	
Wall Sheathing	4" Polyiso R-28 sheathing – Total Wall R-41	
Basement Floor	Under-slab 2" XPS, R-10	
Basement Walls	4" R-28 HD SPF on perimeter walls	
Windows	Andersen Woodwright Replacement Windows Weighted Average U=0.33, SHGC=0.33	
Infiltration	2.0 sq in leakage area per 100 sf of envelope	

How a 100 year old house is renewed to last an additional 100 years


Mechanical Systems	BEFORE
Heating	60% AFUE for the old boiler -gas -delivered by radiators
Cooling	9 EER for the window units
DHW	0.4 EF for hot water efficiency- AVERAGE summer efficiency is much worse winter efficiency would be about at 60% (since the boiler is heating the house already)

Mechanical Systems	AFTER
Heat	Sealed combustion 92% AFUE gas boiler boiler in conditioned basement
Cooling	13 SEER split system in conditioned space
DHW	0.80 EF side-arm storage tank
Ducts	R-4.2 flex runouts in dropped ceiling or in floor joists
Leakage	none to outside (5% or less)
Ventilation	Fan Cycler: Supply-only system integrated with AHU 33% Duty Cycle: 10 minutes on; 20 minutes off 60-80 CFM continuous average flow
Return Pathways	Transfer grilles/jump ducts at bedrooms





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The interior 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

Air barrier continuity

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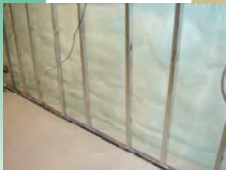
The taped and sealed exterior rigid insulation provides an exterior plane of air tightness to minimize the effects of wind washing of the insulation

Air barrier continuity

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Continuity of the air barrier is maintained with the self-adhered sub-sill flashing membrane overlapping the draining housewrap and expanding foam sealant at the window perimeter

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

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

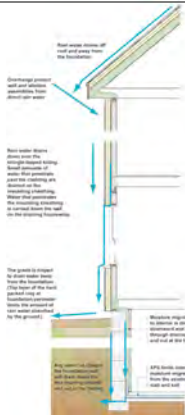
The plane of air tightness for the basement floor is the concrete slab

Air barrier continuity

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Rain water drains off roof and away from foundation

Drainage plane is provided by the self-adhered sub-sill flashing membrane overlapping the draining housewrap and expanding foam sealant at the window perimeter

Rain water drains down the shingle-lapped siding. Small amounts of water that penetrate past the cladding are drained on the insulating sheathing. Water that penetrates the insulating sheathing is carried down the wall on the draining housewrap.

The ground is sloped to drain away from the foundation. The drainage plane is provided only at the window perimeter. Rain water penetrates the wall and is drained to the ground.

Water that penetrates the wall and is drained to the ground.


APU (Air Purge Unit) is used to maintain the drainage plane and prevent water from entering the building.

Drainage plane continuity

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Rain water drains off roof and away from the foundation


Overhangs protect wall and window assemblies from direct rain water

Drainage plane continuity

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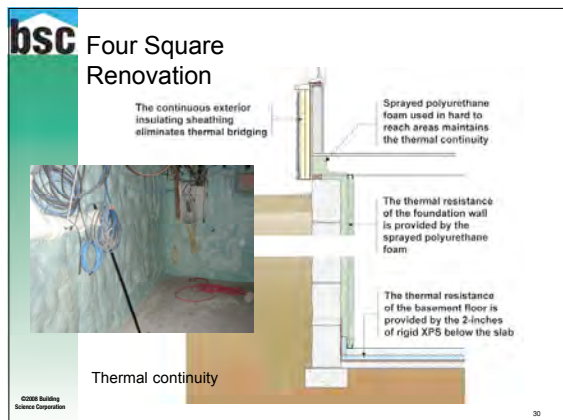
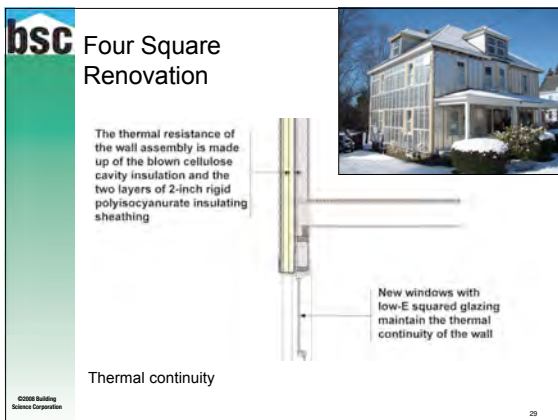
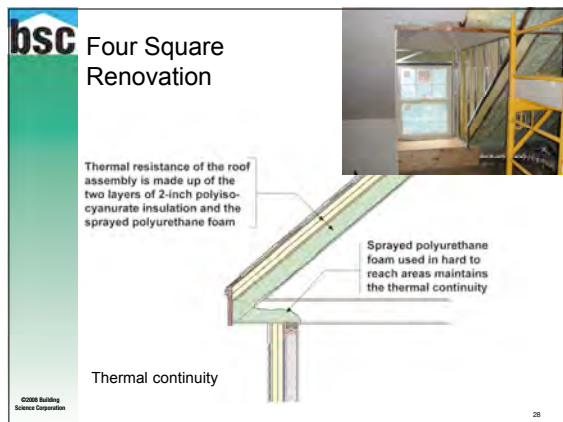
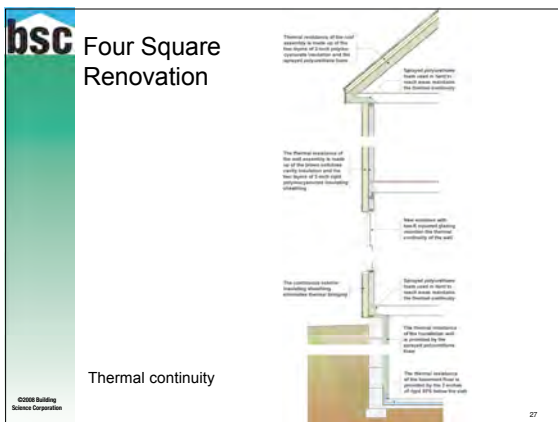
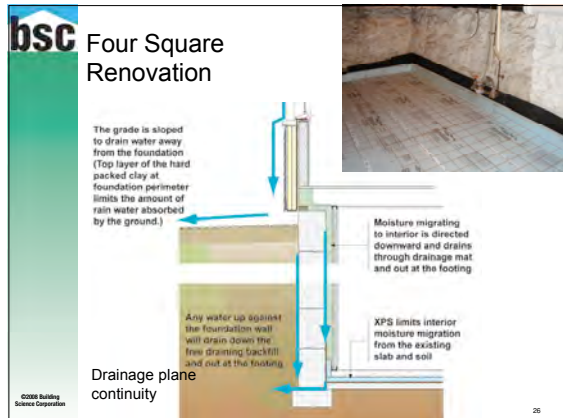


Rain water drains down over the shingle-lapped siding. Small amounts of water that penetrate past the cladding are drained on the insulating sheathing. Water that penetrates the insulating sheathing is carried down the wall on the draining housewrap.

Drainage plane continuity

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Polyisocyanurate elevates the surface temperature of the exterior sheathing during the winter to reduce the condensation potential.
 Semi-permeable interior latex paint finish on gypsum board reduces moisture flow from interior during winter yet still allows drying to the interior during summer.
 Cellulose insulation acts as a hygric buffer by safely storing moisture until it can dry to either the interior or exterior.
 Polyisocyanurate sheathing from the existing slab and soil.
 Exposed portion of foundation wall able to dry to the exterior.
 Drainage mat limits interior moisture migration from the existing slab and soil.

Vapor barrier continuity

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Polyisocyanurate limits moisture flow from the interior during winter.
 Drying primarily to the interior.

Vapor barrier continuity

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Polyisocyanurate elevates the surface temperature of the exterior sheathing during the winter to reduce the condensation potential.
 Semi-permeable interior latex paint finish on gypsum board reduces moisture flow from interior during winter yet still allows drying to the interior during summer.
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Vapor barrier continuity

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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.

Vapor barrier continuity

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bsc New Windows

Photos courtesy of Dan Morrison, *Fine Homebuilding Magazine*

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