Four Square Revisited
Toward Zero Energy Renovation

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Assessing the Impact of US Housing

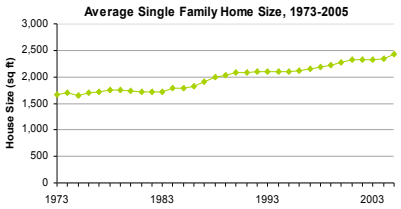
Background:

- **Total Housing Units in 2001 (millions):**
  - Single-Family Homes 73.7
    (2/3 built prior to 1970)
  - Apartments (all buildings) 26.5
  - Mobile Homes 6.8
    107.0 million units[1]
- **Total Residential Energy Use in 2001:**
  - 20,228,107 million Btu[2]

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

Getting Bigger as Time Goes On

- Average House Size in **1940:** **~1100 sq ft**[1]
- Average House Size in **1973:** **1660 sq ft**[2]

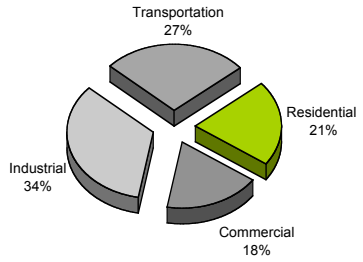


- Average House Size in **2005:** **2434 sq ft**

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

Assessing the Impact of US Housing

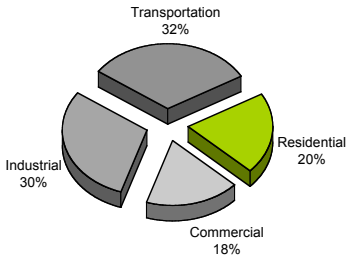
Primary Energy Consumption by Sector, 2001



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

Contribution to Climate Change

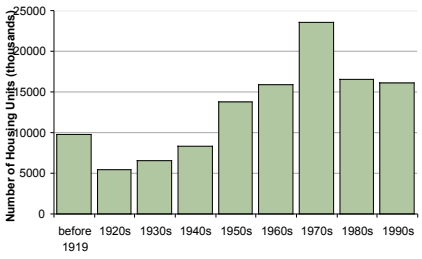
Carbon Dioxide Emissions from Energy Consumption by Sector, 2001



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

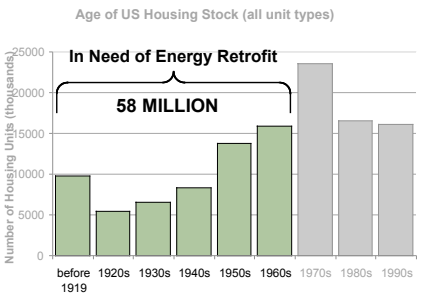
Existing Housing Stock

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



Source: US Census Bureau, Annual Housing Survey:
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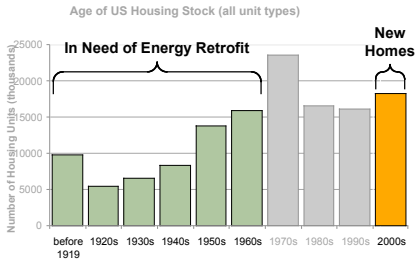
Existing Housing Stock



Source: US Census Bureau, Annual Housing Survey:
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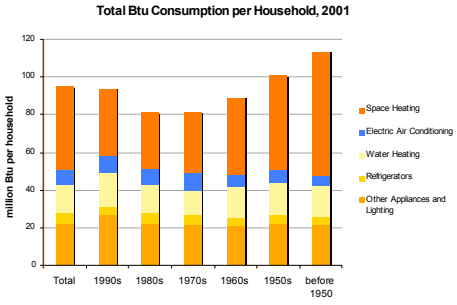
How Old and New Houses Use Energy



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

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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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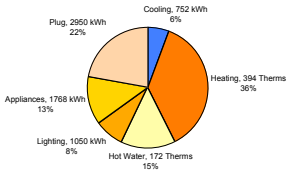
Remaining Loads

6520 kWh and 566 Therms Predicted

Boston Area Super-Insulated 4 BR House
Energy Consumption with Average US Usage



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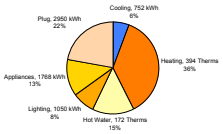
Actual First Year
3200 kWh and 566 Therms

Electric @ $.15 /kWh Gas @ $1.50/therm
Electric $471 Gas $858
Electric/mth - $39 Gas/mth = $71

Boston Area Super-Insulated 4 BR House
Energy Consumption with Average US Usage



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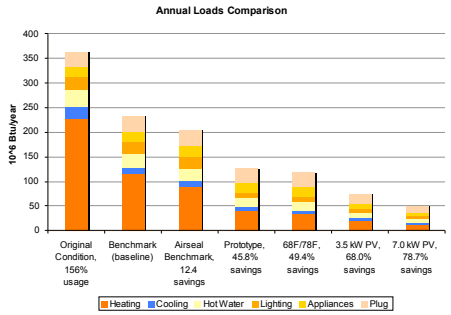
Load Reduction by Conservation - 360 > 120 kBtu's
Then add Site Generated Energy



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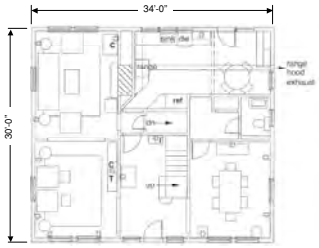
Four Square Renovation



First floor plan

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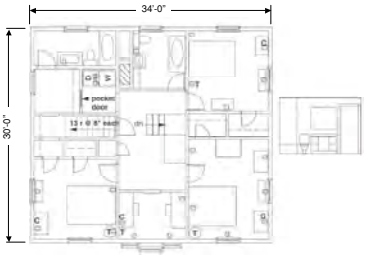
Four Square Renovation



Second floor plan

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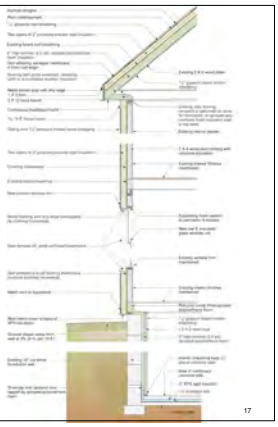
Four Square Renovation

Cross section through house



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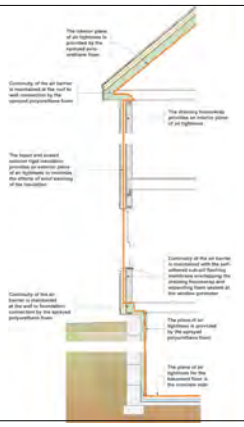

Air barrier continuity

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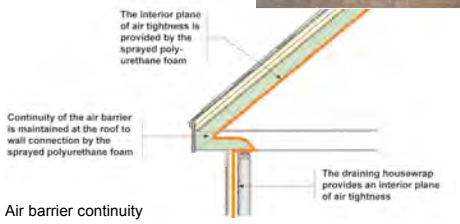
Four Square Renovation



Air barrier continuity

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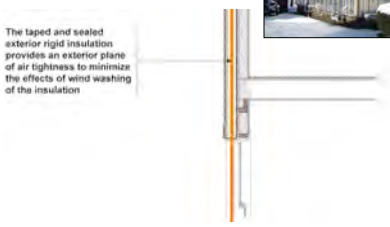
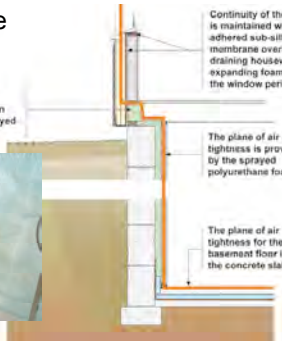
Four Square Renovation



Air barrier continuity

20

Four Square Renovation



Air barrier continuity

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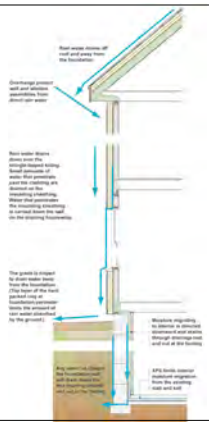
Four Square Renovation



Drainage plane continuity

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Four Square Renovation

Drainage plane continuity

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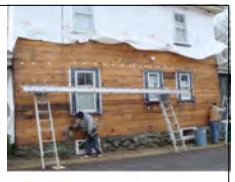
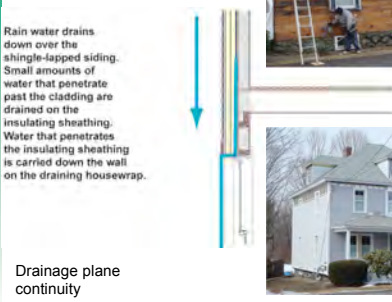
Four Square Renovation





Drainage plane continuity

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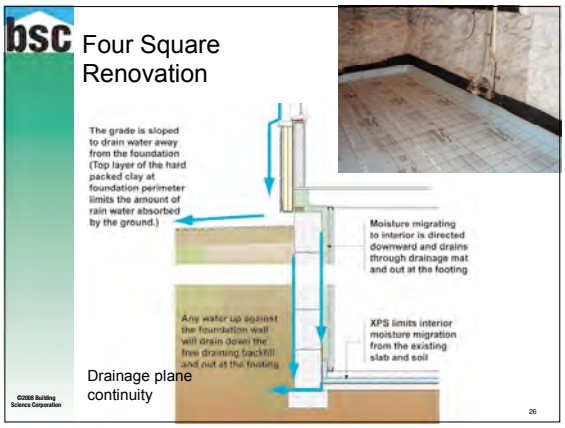

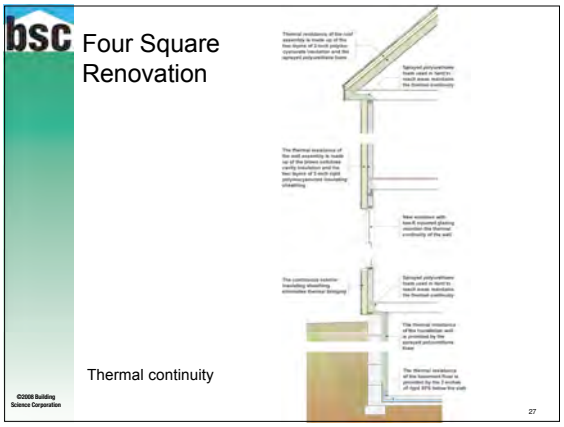

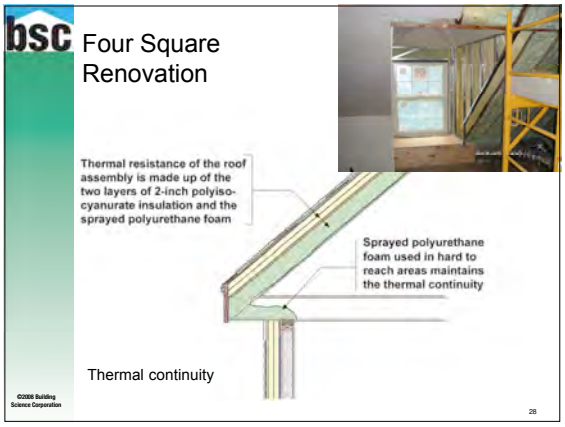

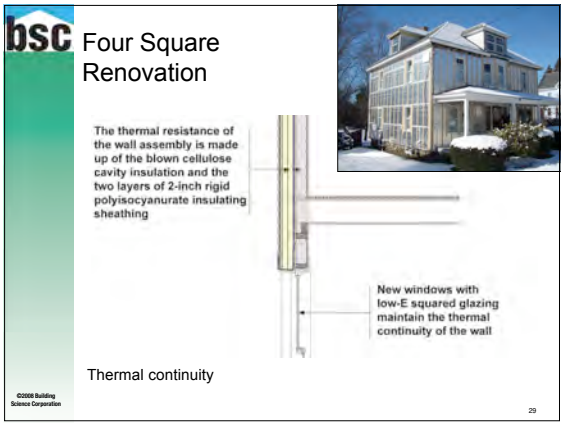

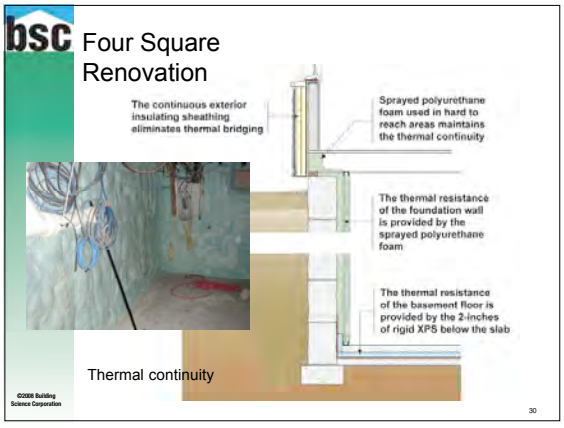

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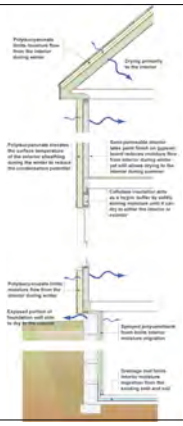

Vapor barrier continuity

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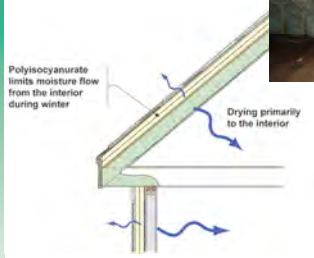
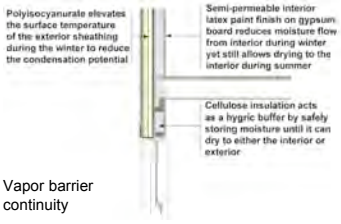
Four Square Renovation



Vapor barrier continuity

32

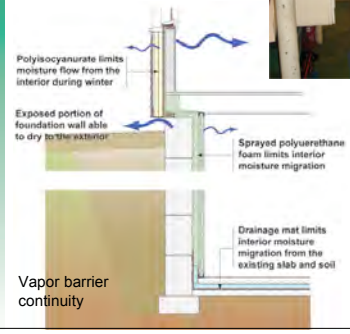
Four Square Renovation



Vapor barrier continuity

33

Four Square Renovation



Vapor barrier continuity

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New Windows

Photos courtesy of Dan Morrison, *Fine Homebuilding Magazine*

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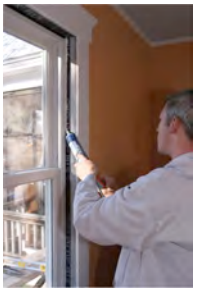
New Windows



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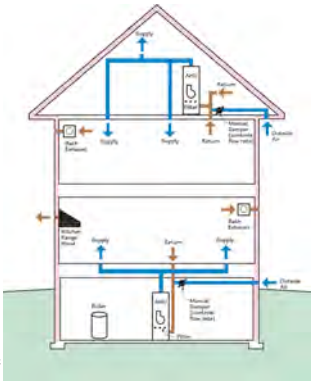

Mechanical schematic

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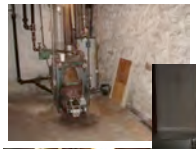
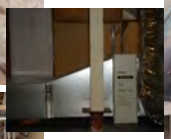
Old Boiler to New Boiler plus air handlers, outside air intake, filtration, and exhaust at baths and kitchen





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