Four Square Revisited
Toward Zero Energy Renovation

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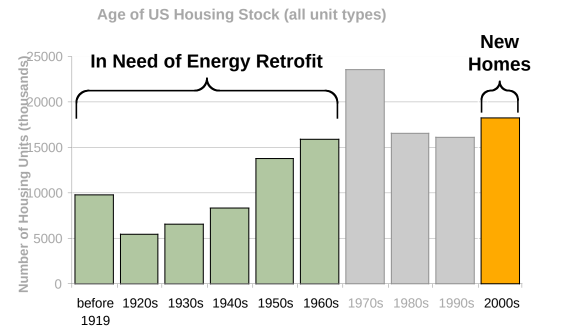
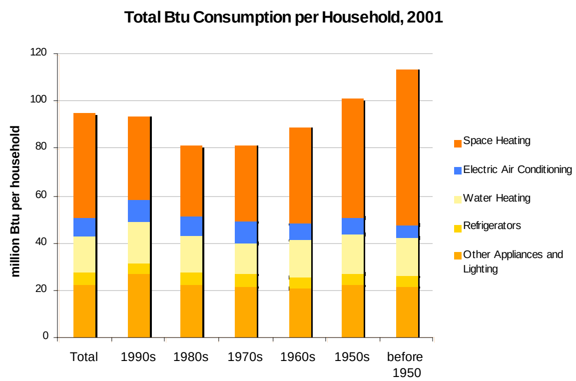
Existing Housing Stock



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

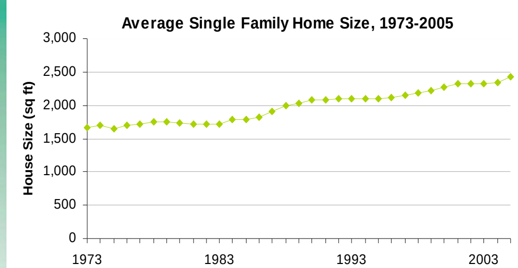
How Old and New Houses Use Energy



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

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

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	

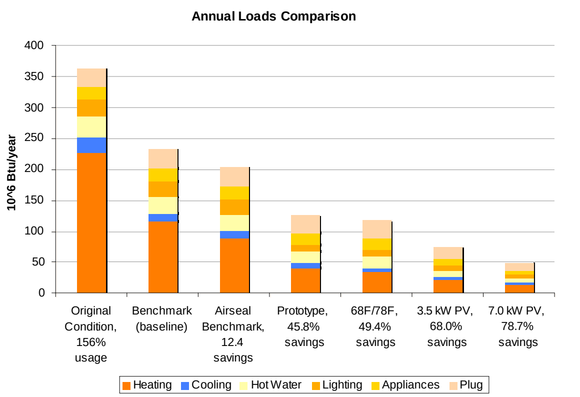
Building Enclosure	AFTER	CONDITIONED SQ. FT. = 3,600
Conditioned Attic		R-39 High Density Spray Foam on sheathing
		R-21 roof deck insulation – Total Roof R-60
Walls		R-13 cellulose blown into existing 2x4 walls
Wall Sheathing		4" Polyiso R-28 sheathing – Total Wall R-41
Basement Floor		Under-slab 2" 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)

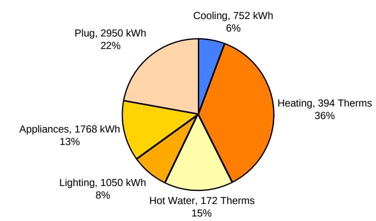
Mechanical Systems	AFTER	
Heat		Sealed combustion 92% AFUE gas boiler
		boiler in conditioned basement
Cooling		14 SEER split system in conditioned space
DHW		0.80 EF side-arm storage tank
Ducts		R-4.2 flex runouts in dropped ceiling or in floor joists
Leakage		none to outside (5% or less)
Ventilation		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

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



Remaining Loads
6520 kWh and 566 Therms Predicted

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



Actual First Year
3200 kWh and 570 Therms

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

Adding Photovoltaic

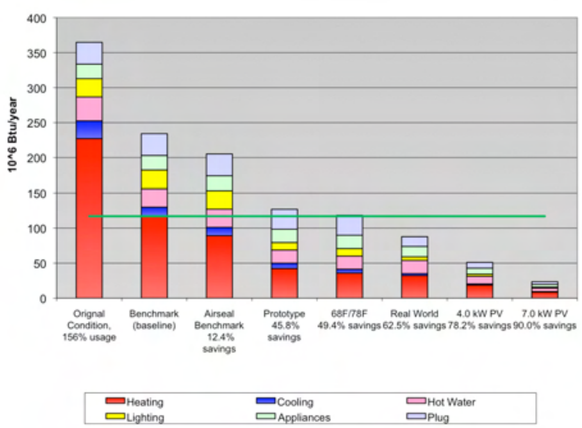
- The electric use was about 300 kWh per month
- A 4kW PV system will create about 300 kWh per month
- At $4 per kW the system would cost $16,000
- The electric bill over 32 year at this rate would be $16,000
- $16,000 at 5.6% will cost $92 per month

Actual First Year
3200 kWh and 570 Therms

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

Adding Solar Hot Water

- A 64 sq. ft. glycol SHW installed with storage = $6,000
- This would create about 180 therms
- At $1.50 per therm the savings would be $270 per year
- Over 22 years at this rate savings would = $6,000
- $6,000 at 5.6% would cost $35 per month

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Second floor plan

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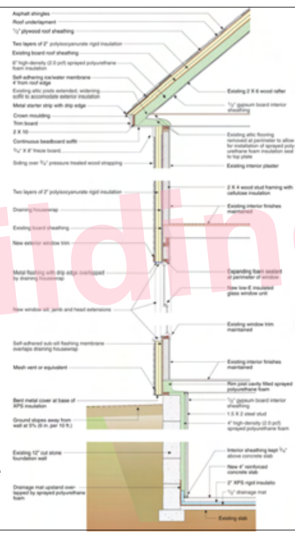

Cross section through house

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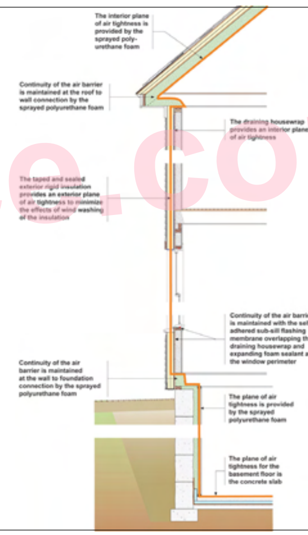
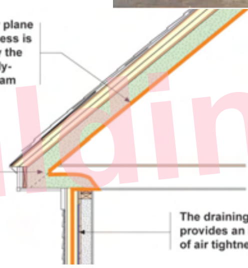


Air barrier continuity

Four Square Renovation



Air barrier continuity

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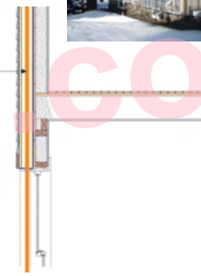
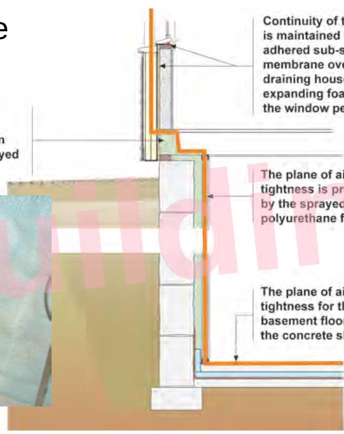


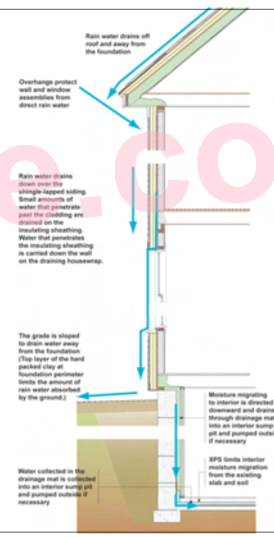
Air barrier continuity

Four Square Renovation



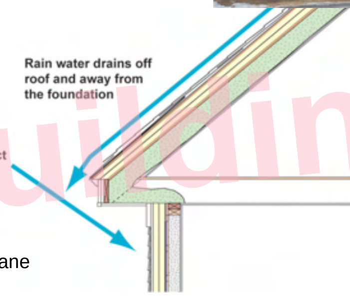
Air barrier continuity

Four Square Renovation



Drainage plane continuity

Four Square Renovation



Drainage plane continuity

Four Square Renovation

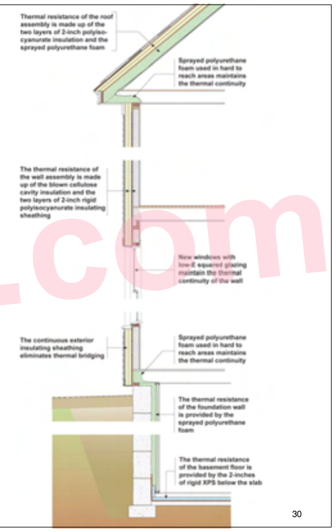
Rain water drains down over the shingle-lapped siding. Small amounts of water that penetrate past the cladding are drained on the insulating sheathing. Water that penetrates the insulating sheathing is carried down the wall on the draining housewrap.

Drainage plane continuity

Four Square Renovation

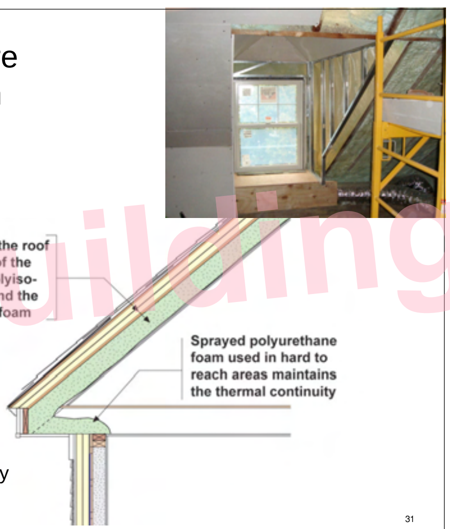
Drainage plane continuity

Four Square Renovation



Thermal continuity

Four Square Renovation



Thermal continuity

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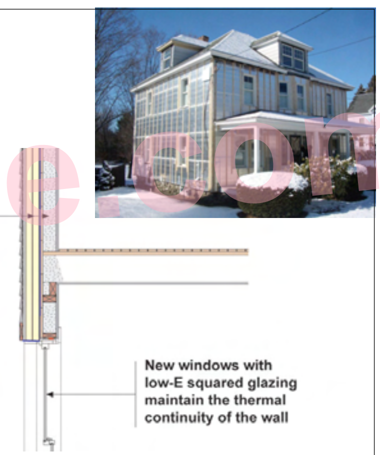
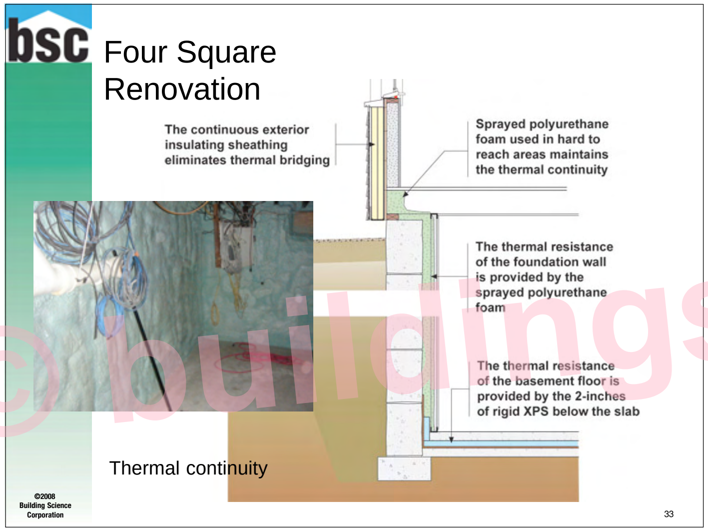


Thermal continuity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Four Square Renovation
The continuous exterior insulating sheathing eliminates thermal bridging
Sprayed polyurethane foam used in hard to reach areas maintains the thermal continuity
The thermal resistance of the foundation wall is provided by the sprayed polyurethane foam
The thermal resistance of the basement floor is provided by the 2-inches of rigid XPS below the slab
Thermal continuity
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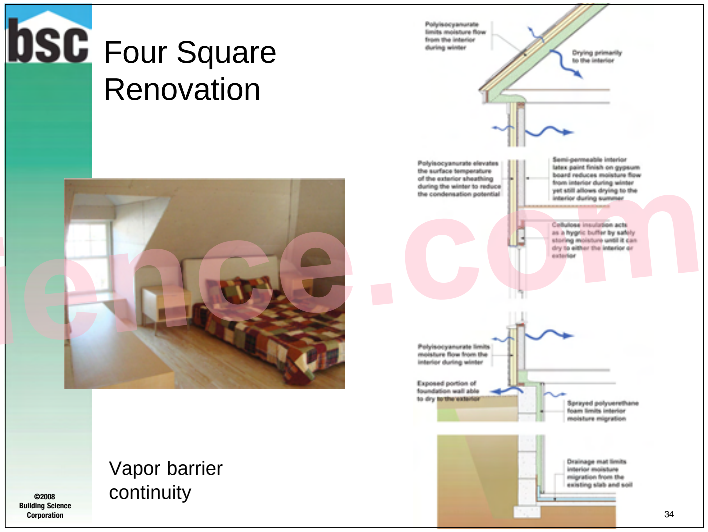
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Four Square Renovation
Polyisocyanurate limits moisture flow from the interior during winter
Drying primarily to the interior
Polyisocyanurate elevates the surface temperature of the exterior sheathing during the winter to reduce the condensation potential
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 limits moisture flow from the interior during winter
Exposed portion of foundation wall able to dry to the exterior
Sprayed polyuerethane foam limits interior moisture migration
Drainage mat limits interior moisture migration from the existing slab and soil
Vapor barrier continuity
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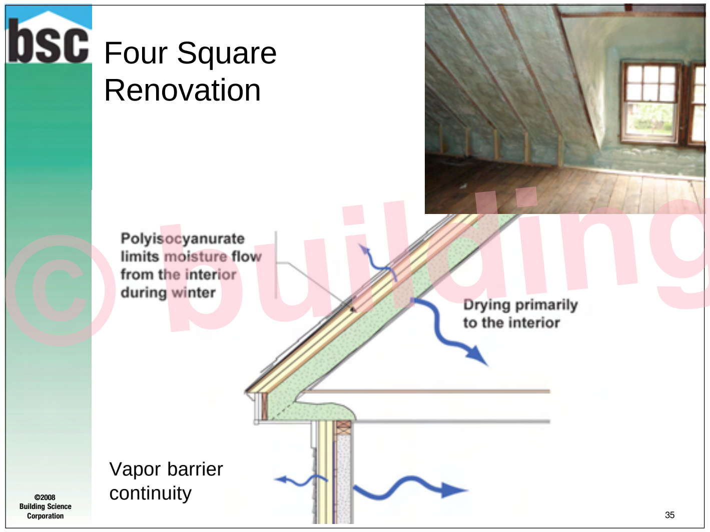
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Four Square Renovation
Polyisocyanurate limits moisture flow from the interior during winter
Drying primarily to the interior
Vapor barrier continuity
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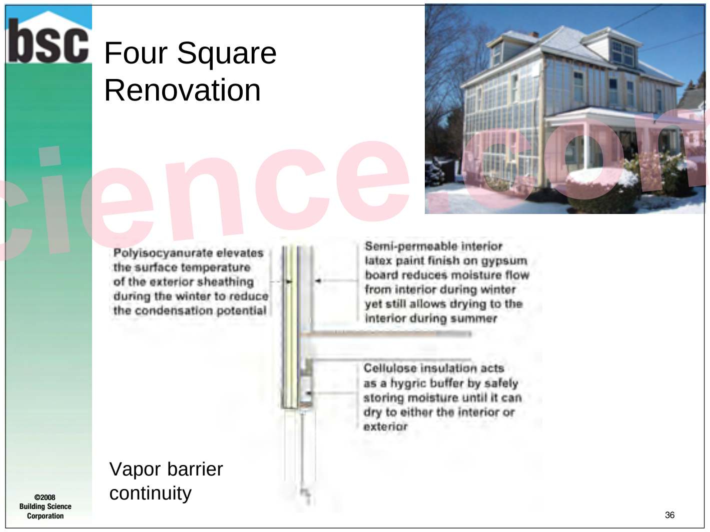
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Semi-permeable interior latex paint finish on gypsum board reduces moisture flow from interior during winter yet still allows drying to the interior during summer
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Vapor barrier continuity
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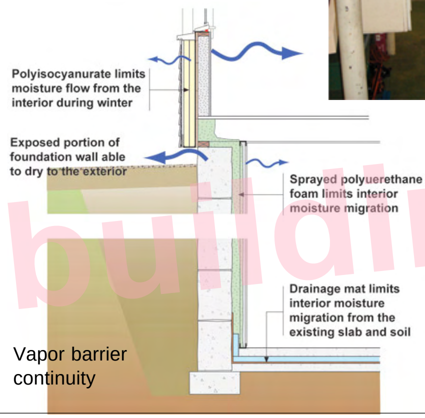
Four Square Renovation



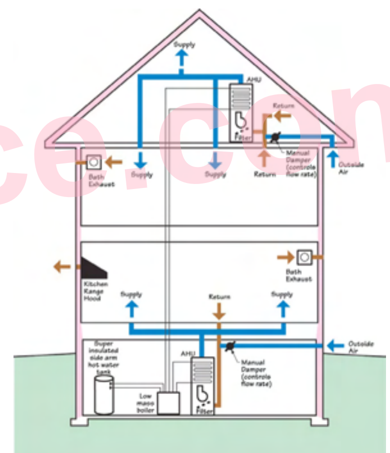
Vapor barrier continuity

New Windows

Photos courtesy of Dan Morrison, *Fine Homebuilding Magazine*

New Windows

Four Square Renovation



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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