Extreme Home Makeover
The Real Deal

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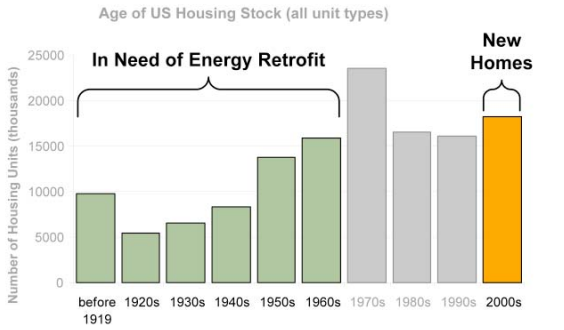
www.buildingscience.com

BSC BEC
Boston, MA October 26, 2009

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

1

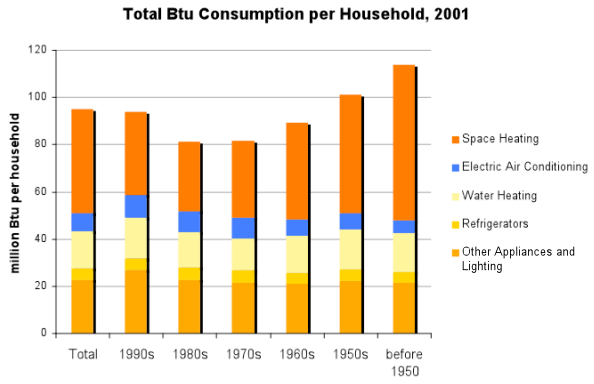
Existing Housing Stock
60 million pre 1970 in need of upgrading



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

2

How Old and New Houses Use Energy



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

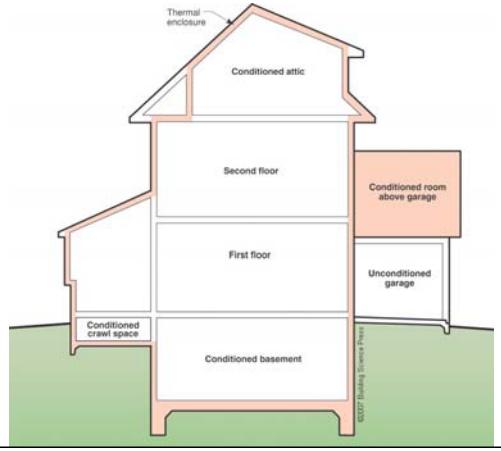
3

The Whole Building Approach

- Performance Issues driving Retrofit:
  - **Comfort**
  - **More use**
  - **Health**
  - **Durability**
  - **Operating Costs**
  - **Energy Efficiency**

4

Expansion of space



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Choices

- 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!

6

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 hot water
- Low-temperature (more efficient) systems can be used
- For ventilations load add HRV
- Variable speed fans and CO_2 controls

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Enclosure Retrofit

- Important target for many buildings
  - Airtightness
  - Windows
  - Insulation
    - Roof
    - Walls
    - Basement
    - Slabs
- Prioritize by Ease and Impact

8

Deep Retrofit

- Significant upgrades are incrementally less expensive
  - Small upgrades very cost effective, but small (10-25% reductions)
  - mid-range upgrades (15-50%) usually really expensive per energy saved
- Deep retrofits (>50%) secure buildings future
  - Allow for new styles, use, etc.
  - Leap frog current housing

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This Deep Energy Retrofit Reduced the Energy Consumption of the home by over 70%

10

The house is now ready for the next 100 years

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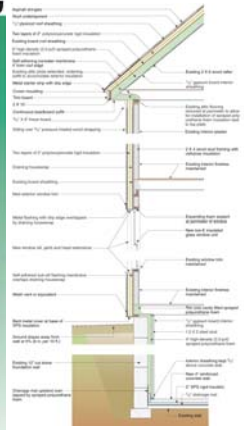

MEASURE	PRERETROFIT	FINAL
Foundation walls (basement)	Uninsulated 12" cut stone	R-20, 4" high density (2.0 pcf) spray polyurethane foam
Slab insulation	None	R-10, 2" XPS insulating sheathing under slab
Above-grade walls	Some slag wool	R-41: blown cellulose cavity insulation and two layers of 2" polyisocyanurate rigid on the exterior
Siding	Aluminum siding over original shingles	Cedar siding over 3/4" wood strapping (rain-screen cavity)
Band joist areas	No insulation	Cavity filled with spray polyurethane foam
Cathedral ceilings	N/A	Two layers of 2" polyisocyanurate rigid insulation on top of roof sheathing with 6" high density (2.0 pcf) spray polyurethane foam in the existing 2x6 wood rafter
Flat ceilings	10" loose blown slag wool	N/A
Basement windows	Single-pane wood framed	Double-glazed, Low-E, argon-filled: U=33, SHGC=0.32; new window sill, jamb and head extensions, expanding foam sealant at window perimeter
Above-grade windows	Single-pane wood framed with aluminum storm windows	Double-glazed, Low-E, argon-filled: U=33, SHGC=0.32; new window sill, jamb and head extensions, expanding foam sealant at window perimeter
Exterior doors	Solid wood stile and rail	Kept existing front door

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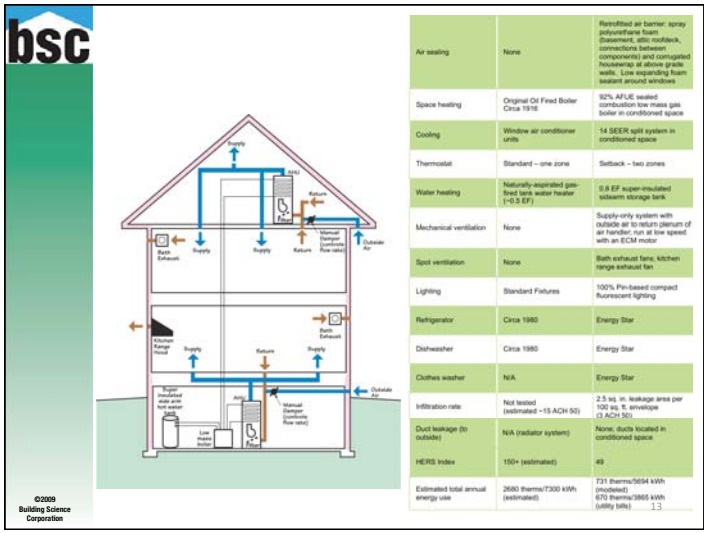
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Supply
Return
Bath Exhaust
Supply
Supply
Return
Manual Damper (controls flow ratio)
Outside Air
Kitchen Range Hood
Bath Exhaust
Supply
Return
Supply
Outside Air
Manual Damper (controls flow ratio)
Low mass boiler
Air Filter
Air Handler
Air Filter
Air Handler
Air sealing
None
Retrofitted air barrier: spray polyurethane foam (basement, attic roofdeck, connections between components) and corrugated housewrap at above grade walls. Low expanding foam sealant around windows
Space heating
Original Oil Fired Boiler Circa 1918
92% AFUE sealed combustion low mass gas boiler in conditioned space
Cooling
Window air conditioner units
14 SEER split system in conditioned space
Thermostat
Standard – one zone
Setback – two zones
Water heating
Naturally-aspirated gas-fired tank water heater (~0.5 EF)
0.8 EF super-insulated sidearm storage tank
Mechanical ventilation
None
Supply-only system with outside air to return plenum of air handler; run at low speed with an ECM motor
Spot ventilation
None
Bath exhaust fans; kitchen range exhaust fan
Lighting
Standard Fixtures
100% Pin-based compact fluorescent lighting
Refrigerator
Circa 1980
Energy Star
Dishwasher
Circa 1980
Energy Star
Clothes washer
N/A
Energy Star
Infiltration rate
Not tested (estimated ~15 ACH 50)
2.5 sq. in. leakage area per 100 sq. ft. envelope (3 ACH 50)
Duct leakage (to outside)
N/A (radiator system)
None; ducts located in conditioned space
HERS Index
150+ (estimated)
49
Estimated total annual energy use
2680 therms/7300 kWh (estimated)
731 therms/3694 kWh (modeled)
670 therms/3865 kWh (utility bills)
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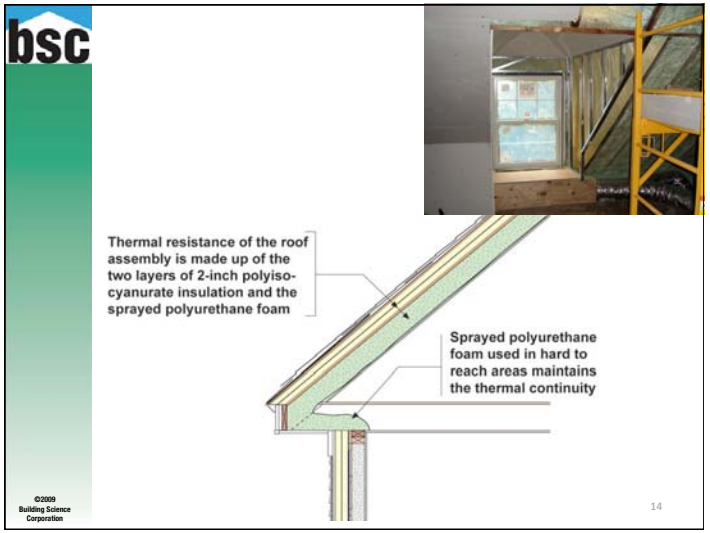
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Thermal resistance of the roof assembly is made up of the two layers of 2-inch polyiso-cyanurate insulation and the sprayed polyurethane foam
Sprayed polyurethane foam used in hard to reach areas maintains the thermal continuity
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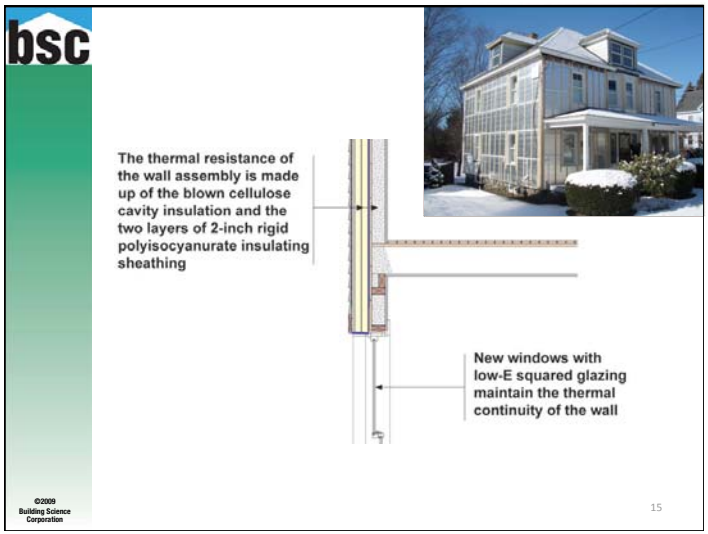
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The thermal resistance of the wall assembly is made up of the blown cellulose cavity insulation and the two layers of 2-inch rigid polyisocyanurate insulating sheathing
New windows with low-E squared glazing maintain the thermal continuity of the wall
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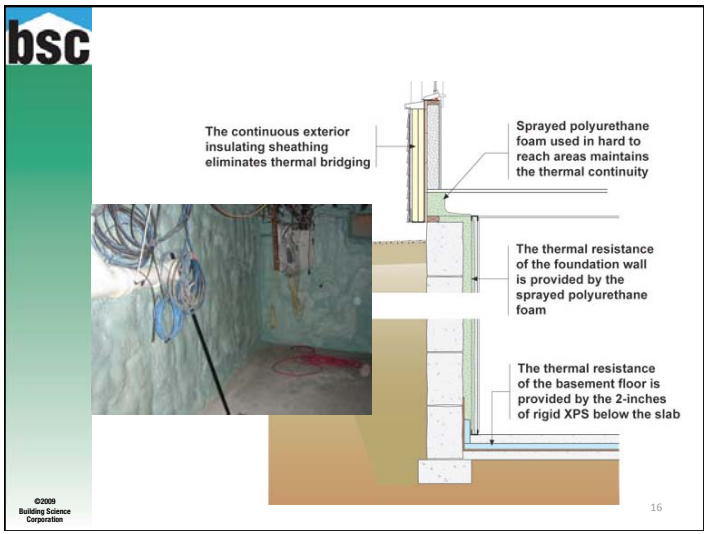
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The continuous exterior insulating sheathing eliminates thermal bridging
Sprayed polyurethane foam used in hard to reach areas maintains the thermal continuity
The thermal resistance of the foundation wall is provided by the sprayed polyurethane foam
The thermal resistance of the basement floor is provided by the 2-inches of rigid XPS below the slab
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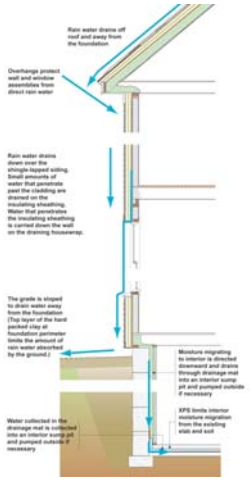
Water Control Layer

Moving rainwater from the roof and walls and groundwater from the foundations



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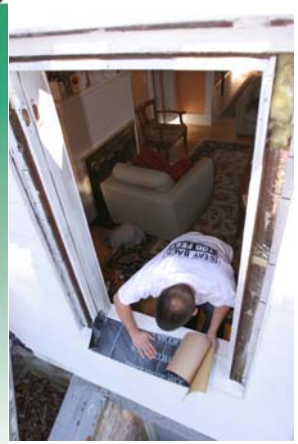

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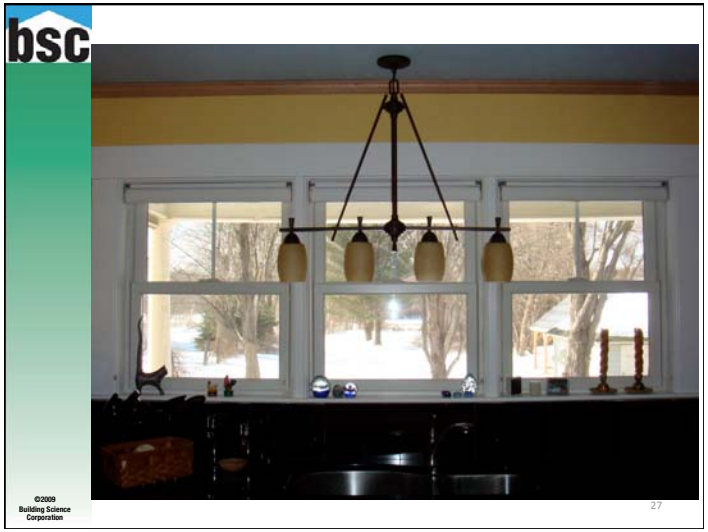
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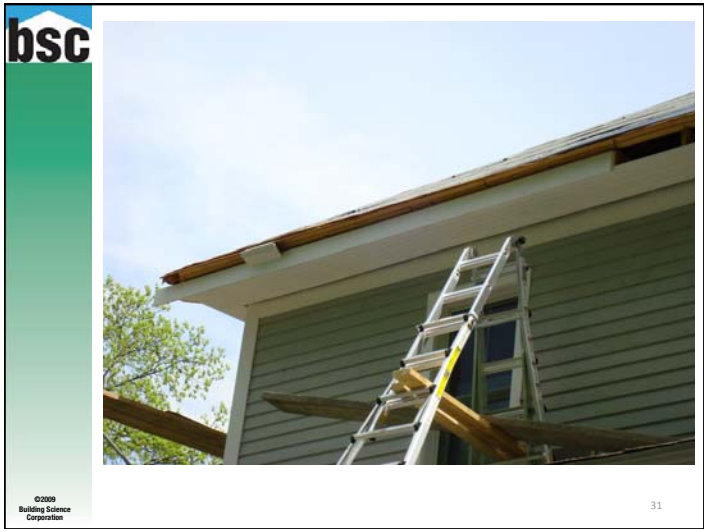
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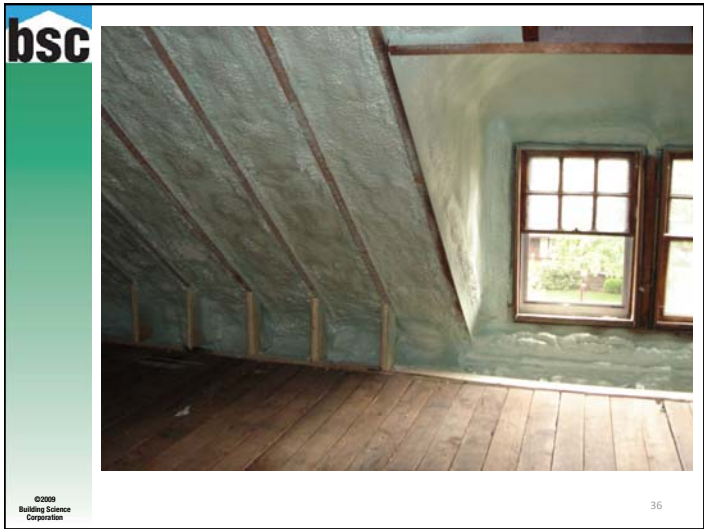
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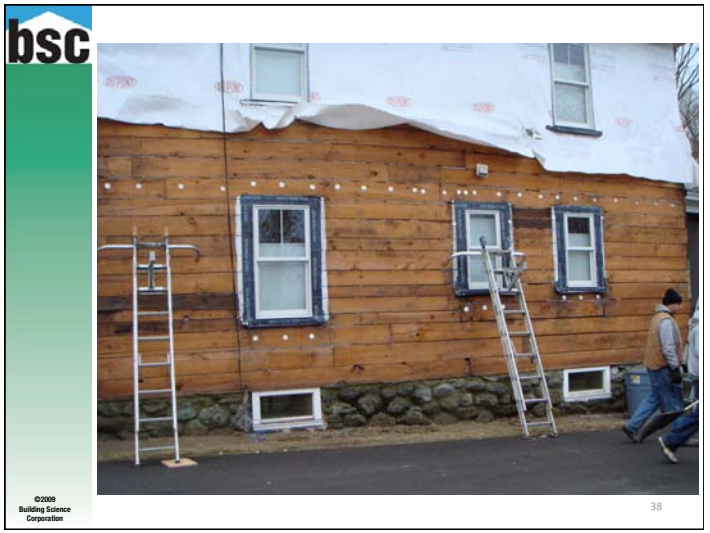
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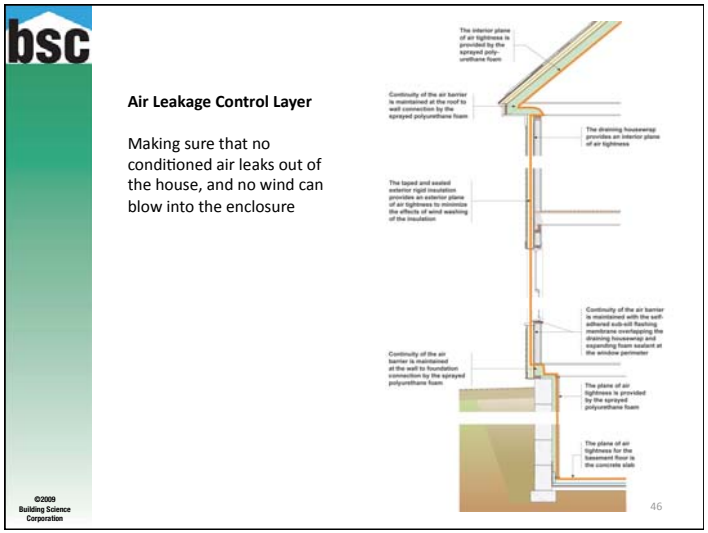
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Air Leakage Control Layer
Making sure that no conditioned air leaks out of the house, and no wind can blow into the enclosure
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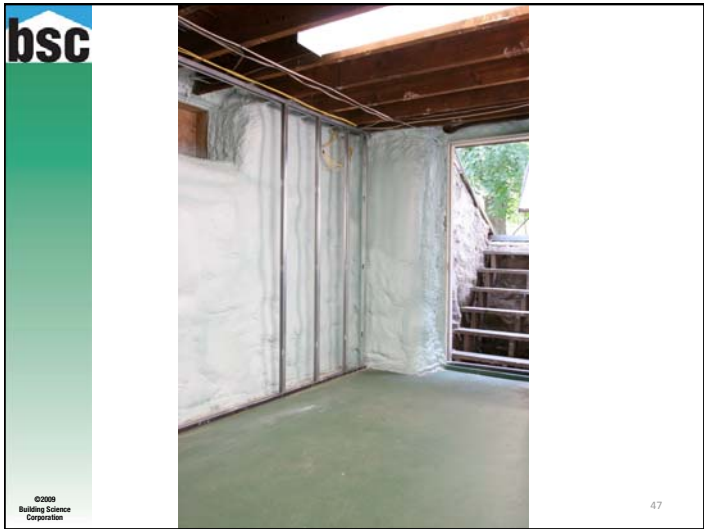
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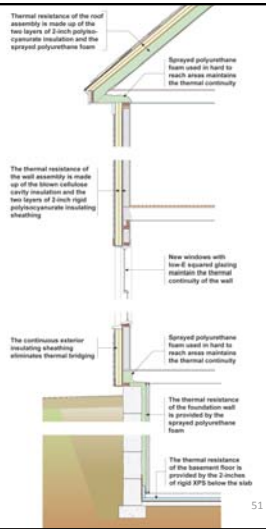
Thermal Control Layer

Must be consistent around all six sides of the cube



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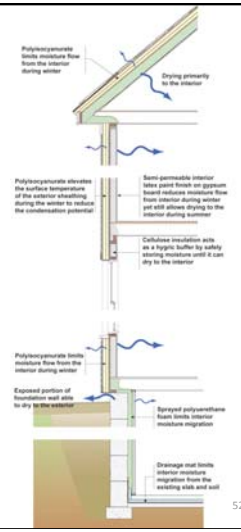
Vapor Control Layer

Make sure that no water in the vapor form gets trapped in assemblies, such that it gets cold enough to condense, turning to liquid water. When this happens things rot, corrode, and environments that are conducive to mold growth are created.



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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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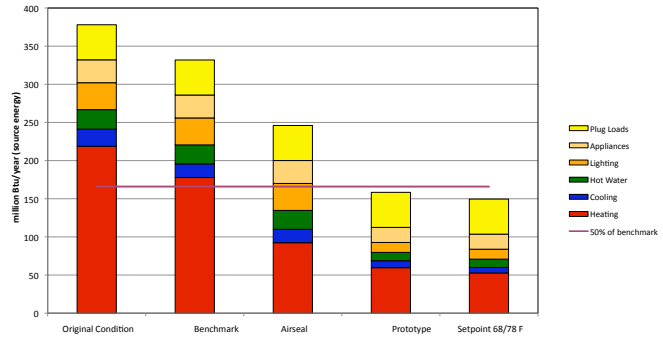
Simulated Improvement Results from Original Condition

(Original Condition > HERS 150



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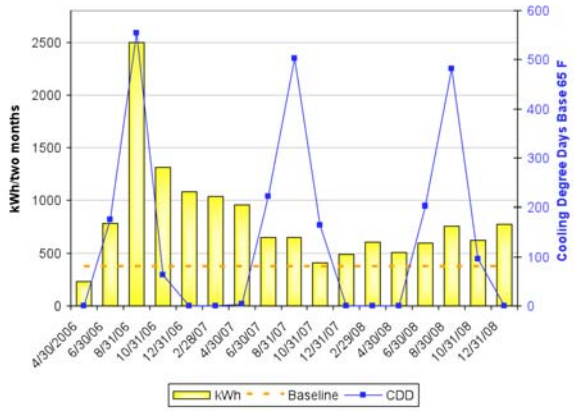

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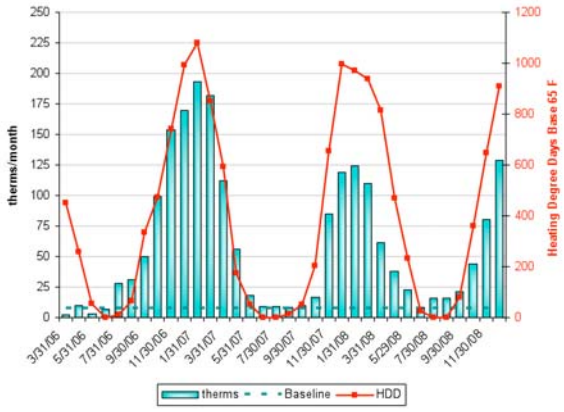

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Actual First Year

3865 kWh and 614 Therms

Electric @ $.15 /kWh Gas @ $1.50/therm
Electric $580 Gas $921
Electric/mth - $47 Gas/mth = $76

Energy Measures =
New Mechanical Systems ($25,000), Insulation ($25,000),
and New Windows ($20,000)

Original oil bills $4,000 per year
Original electric $1,500 per year

Initial Cost Of Measures	Annual Savings	Annual Finance 30 yrs @ 4.5%	Cash Flow
$70,000	$4005	$4248	($243)

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Adding Solar Hot Water

- Add Solar Hot Water to match demand
- A 64 sq. ft. drain-back SHW installed with storage = $6,000
- (this house did not have a good location for the system so it was not used)

Adding Photovoltaic

- A 3.5kW PV system more than offset yearly energy use
- At $4 per W the system cost $14,000

Initial Cost	Annual Savings	Annual Finance	Cash Flow
$6,000	$264	$479	($215)
$14,000	$600	$840	($240)

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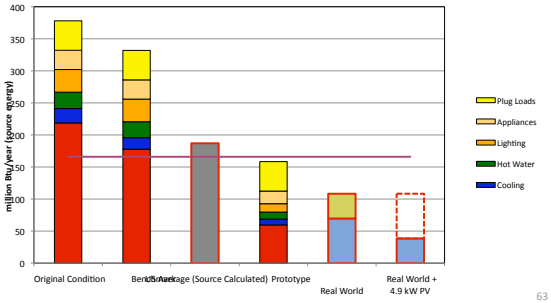
Actual Performance

- Without the PV's, the house had a 72% reduction with respect to its original energy use.
- Without the PV's, the house had a 44% reduction with respect to the national average.
- With the PV's, the house had an 80% reduction with respect to the national average.



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Retrofit of Existing Farmhouse into a 2 Story Single Family Home with 3 Bedrooms and 2.5 Baths

The Farmhouse is located in a Cold Climate, Climate Zone 5A (5596 HDD, 5358 CDH)

Existing Farmhouse

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Farmhouse Retrofit

Bedford, MA

Habitat for Humanity of Greater Lowell

12 May 2009 69

Farmhouse Retrofit

Bedford, MA

Habitat for Humanity of Greater Lowell

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Design Highlights

- High-Performance Building Enclosure Retrofit
- High Efficiency Heating and Hot Water Systems
- Central-Fan-Integrated Ventilation
- New Bedroom and Barrier-Free Full Bath on First Floor
- Affordable Housing Developer
- Volunteer and Student Labor

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Retrofit Challenges to High Performance

- Water Management and Air Barrier Continuity with Thick Insulating Sheathing (*Out*sulation!)
  - Transition air barrier down and in at foundation wall while maintaining water management (down and out!)
  - Roof-Wall interface
- Structural Attachment through Insulating Sheathing
- Windows and Doors
- Room for Mechanical Distribution
- Structural Remediation

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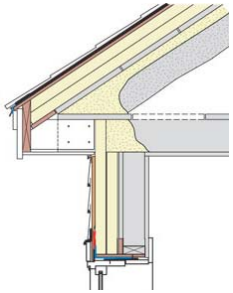
Roof Details

- High Density Spray Foam Air Seal at Roof Perimeter
- Spray Foam Flash Coat 1"-2" (~R6-12) to underside of Roof Sheathing and at Gable Walls
- Cellulose Netted and Blown 2"-4" (~R7-14) between Roof Rafters and Gable Framing
- 4" (R26) Foil-Face Polyiso Insulating Sheathing, in (2) Layers
  - Joints staggered horizontally and vertically
  - All joints taped and sealed
- Nail base, Ice and Water Membrane, Asphalt Shingles



Basement Wall Section

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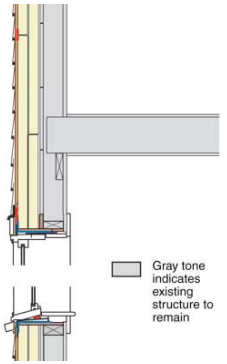
Wall Details

- 4" Cellulose in Walls (R-14)
- 2" – 4" Foil-Faced Polyiso Insulating Sheathing (R-13 to R-26)
  - Joints staggered horizontally and vertically
  - All joints taped and sealed
- Wood furring strips, vinyl siding

High Performance Windows

- U = 0.31, SHGC = 0.32
- Double pane, vinyl-framed, low-e, argon fill



Typical Wall Section

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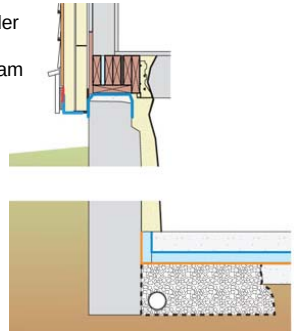
Basement Details

- Capillary Break installed under new sill beam
- 2"-3" High Density Spray Foam (~R13 – R19.5) applied to Rubble Stone Foundation
- Intumescent Paint fire protection for spray foam
- R-10 XPS under New Slab

Perimeter Drain



Basement Wall Section

75

- Window installation

76

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- Mechanical Details
  - 93% AFUE Furnace
  - Ducts in Conditioned Space
  - Ducts Sealed Exceptionally Tight
  - Instantaneous Hot Water Heater EF = 0.82
  - Energy Star Appliances
  - Full CFL Package

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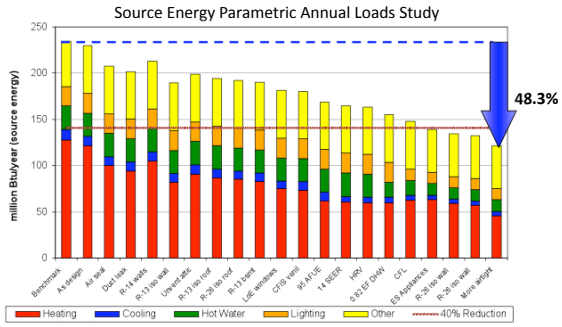
Farmhouse Retrofit

Bedford, MA

Habitat for Humanity of Greater Lowell

- Source Energy Savings



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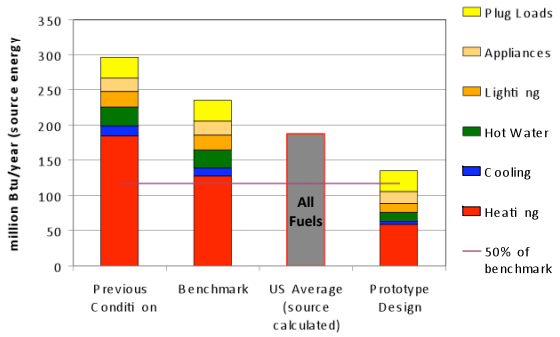
Projected Energy Use



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Freeport Retrofit — Freeport, ME

Warren Construction Group

57 Depot Street prior to construction

Freeport Retrofit — Freeport, ME

Warren Construction Group

- Project Overview
  - Builder: Warren Construction Group
  - Location: Freeport, ME
  - Climate: Cold (6A)
  - Type: Single Family
  - Stories: 2
  - Bedrooms: 3
  - Baths: 1 ½
  - Floor Area: 1,600 sq. ft.
  - Basement Area: 886 sq. ft.

Back of 57 Depot Street

Freeport Retrofit — Freeport, ME

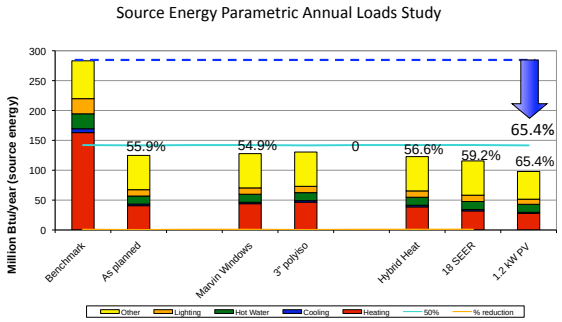
Warren Construction Group

- Project Overview
  - Estimated Energy Reduction: 65.4%
  - Estimated Energy Savings: $4,915 / year
  - Estimated Cost: $250,000 - $300,000
  - Construction Start: September 2009
  - Construction Finish: April 2009
  - Construction Schedule: 8 Months

Freeport Retrofit — Freeport, ME

Warren Construction Group

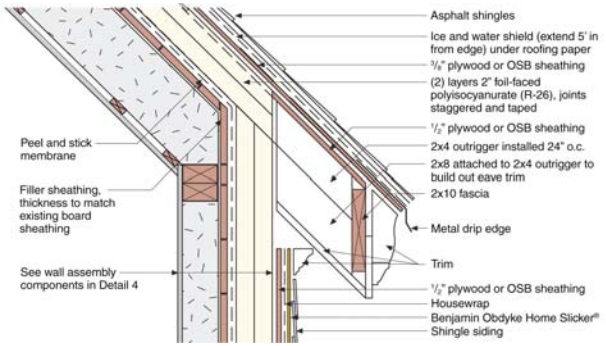
- Source Energy Savings



Wall Section

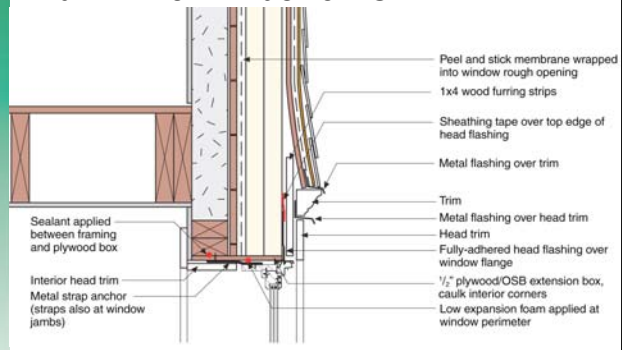
Freeport Retrofit

Roof – R 50



Freeport Retrofit

Wall – R 40 Windows R-5

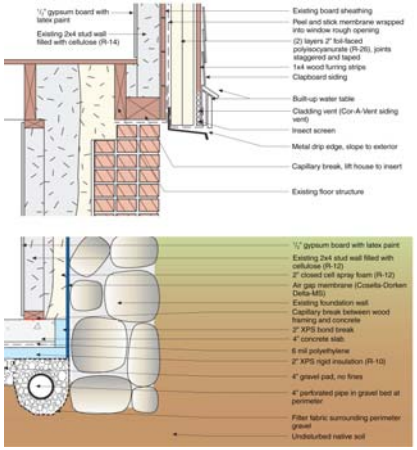


Freeport Retrofit

Foundation

Slab – R-10

Walls – R-12



Freeport Retrofit

Freeport Retrofit

Freeport, ME

Warren Construction Group

- Mechanical Design
  - Hybrid heat system: 96% AFUE gas furnace + 18 SEER/9.1 HSPF air source heat pump
  - Cooling: 18 SEER/9.1 HSPF split system
  - 0.82 EF instantaneous water heater
  - Fantech heat recovery ventilator (HRV)
  - 1.2 kW PV system on southwest facing roof

Example of high efficiency mechanical system

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

For more information go to :

www.affordablecomfort.org
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