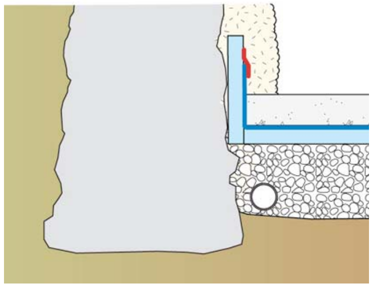
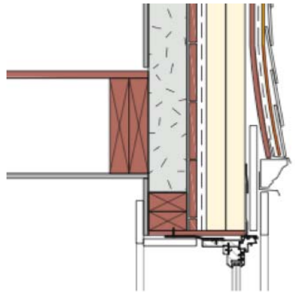
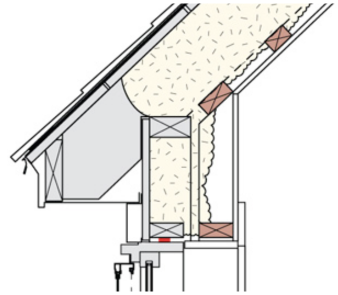
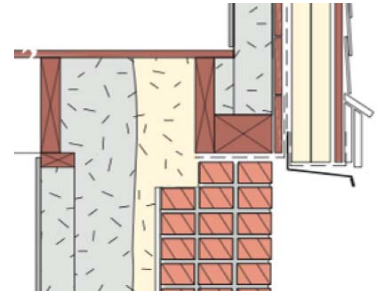
www.buildingscience.com

Betsy Pettit, FAIA

A18 Deep Energy Retrofits for Existing Single Family Homes
Case Studies

Residential Design and Construction 2010
14 April 2010

Deep Energy Retrofit

- There are approximately 60 million units of housing in the U.S. that were built prior to 1960.
- Most of these will need major systems replaced in the near future.
- As siding, windows, and roof claddings need to be replaced, opportunities arise to reduce the overall energy use of these homes.
- Insulating sheathings and new better performing windows will increase comfort while reducing energy use.
- Once enclosure losses are reduced, old boilers, furnaces, and air conditioners can be replaced and downsized with more efficient equipment.
- Whole house ventilation equipment completes the upgrades, insuring good indoor air quality.
- Details and results from several case studies of cold climate deep energy retrofits will be presented.

Assessing the Impact of US Housing

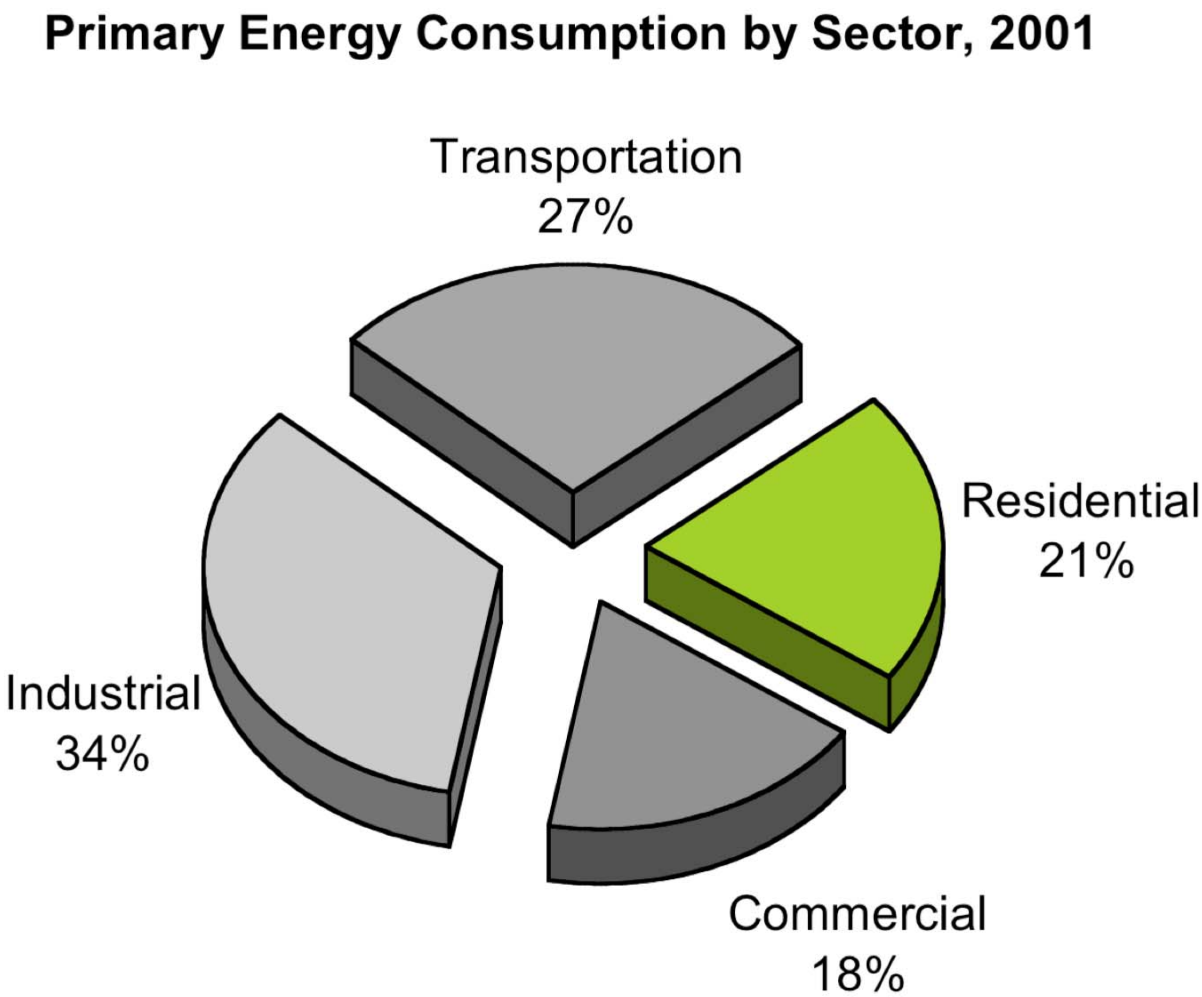
- **Total Housing Units in 2001 (millions):**

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

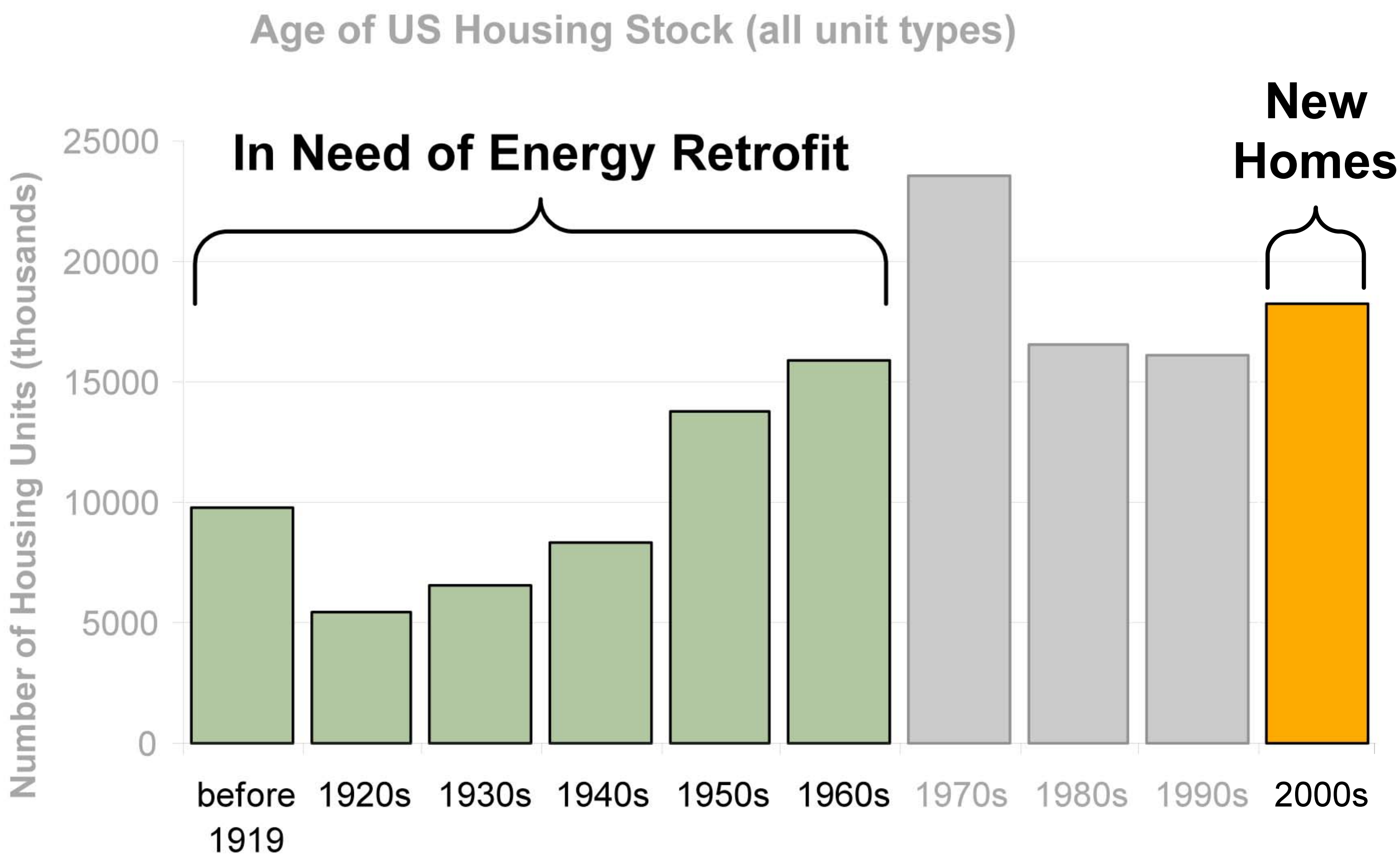
Approx Existing Units: 115 million units[1]

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

Building Energy Use



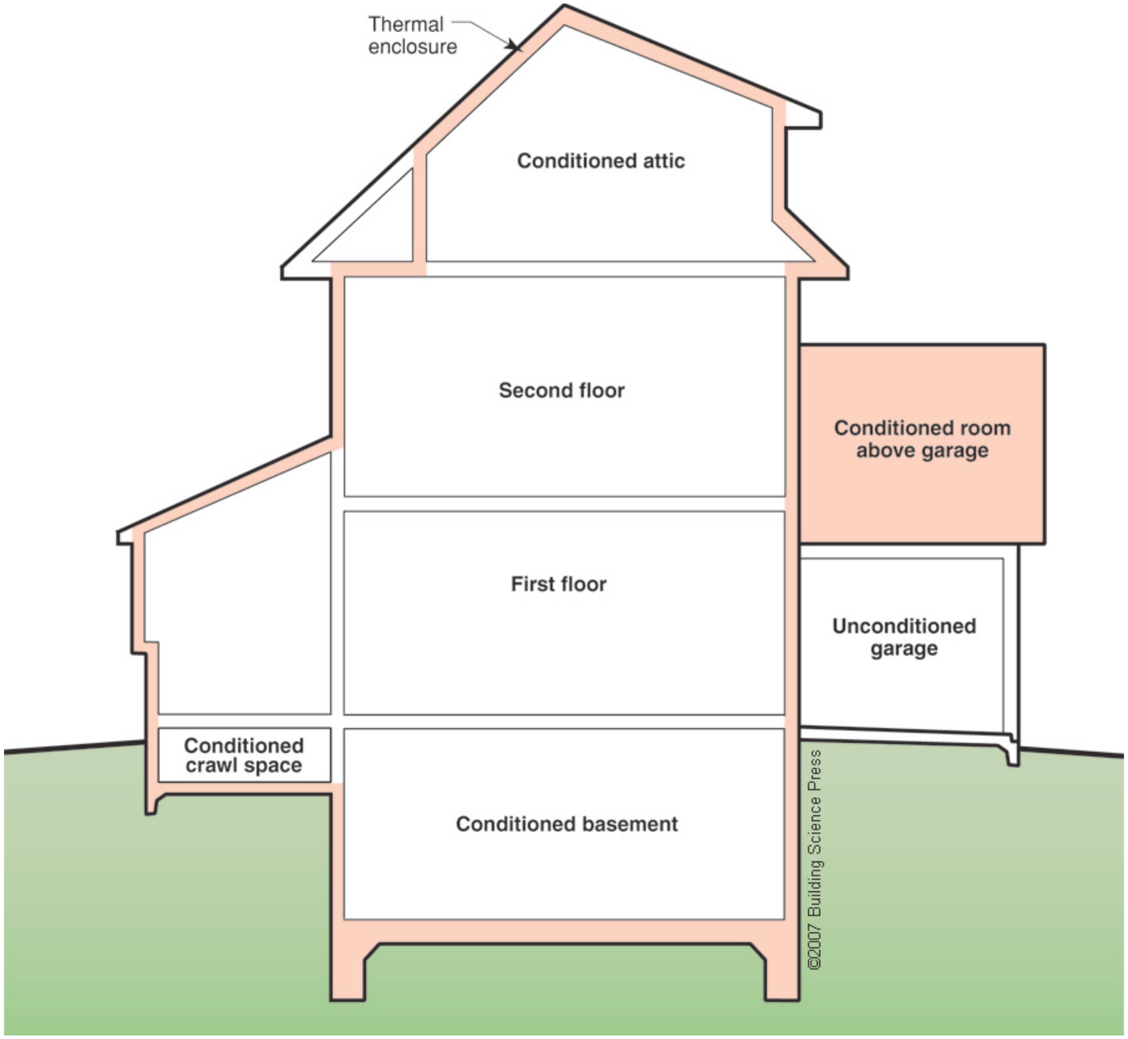
Existing Housing Stock



The Whole Building Approach

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

Expansion of space



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!**

BSI-014

Enclosure Retrofit

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

Mechanical Retrofit

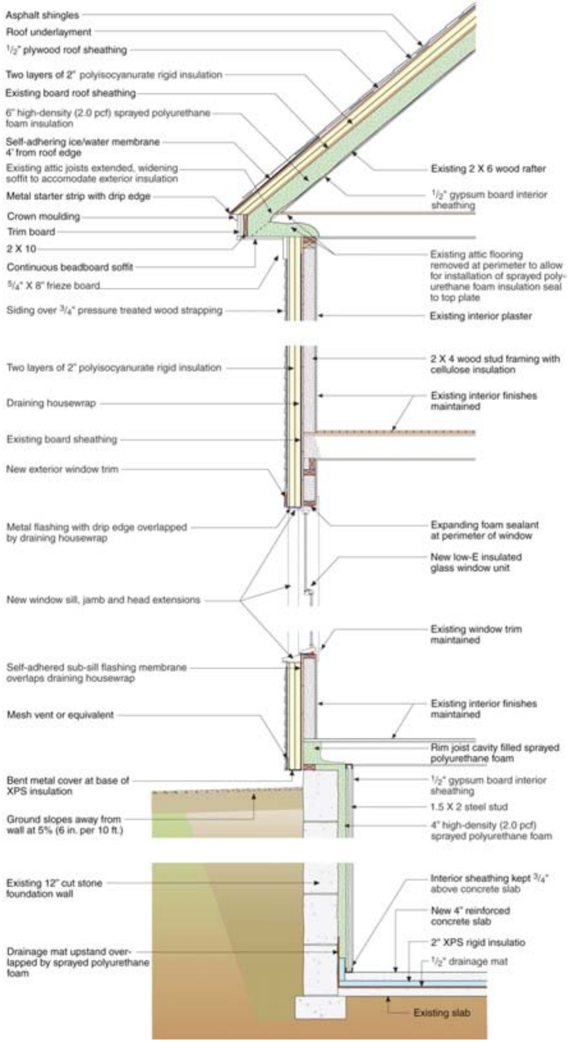
- **After enclosure upgrade**
  - Much smaller and quieter systems can be chosen
- **Air-based can be replaced w/ hydro-air**
- **Steam-based can be replaced hot water**
- **Low-temperature (more efficient) systems can be used**
- **For ventilation load add HRV**
- **Variable speed fans**

Deep Energy 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

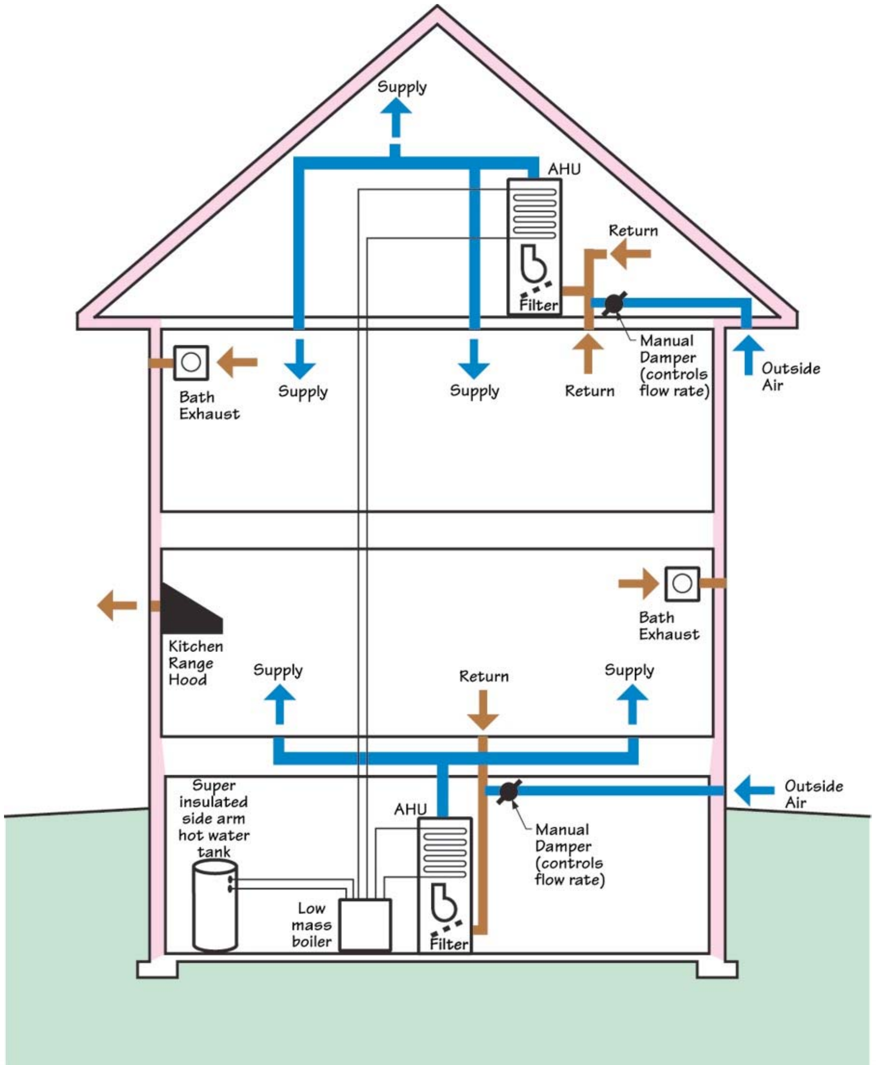
Foursquare – Concord, MA

Deep Energy Retrofit



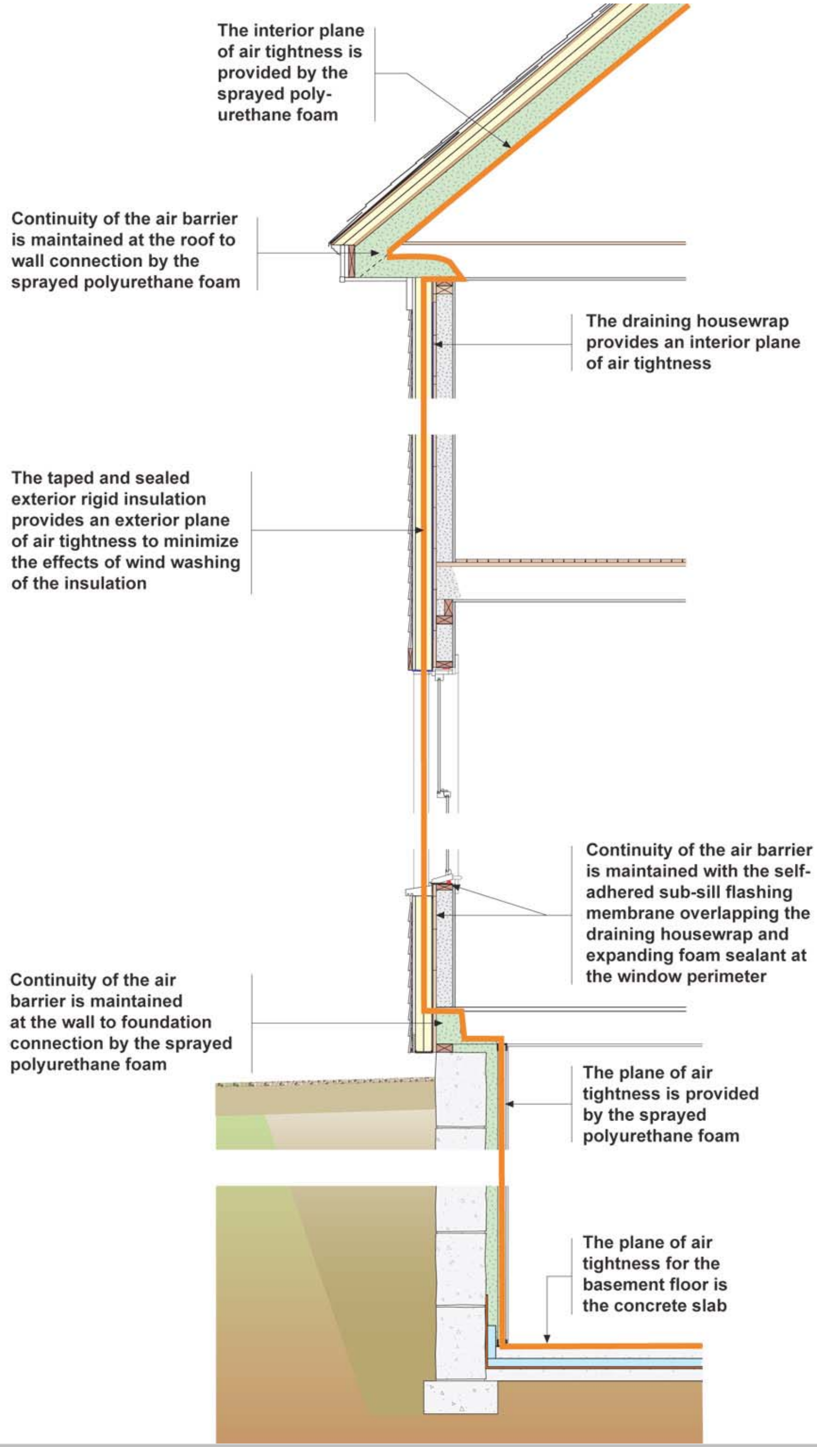
MEASURE	PRERETROFIT	FINAL
Foundation walls (basement)	Uninsulated 12" cut stone	R-20; 4" high density (2.0 pcf) spray polyurethane foam
Slab insulation	None	R-10; 2" XPS insulating sheathing under slab
Above-grade walls	Some slag wool	R-41: blown cellulose cavity insulation and two layers of 2" polyisocyanurate 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

Deep Energy Retrofit

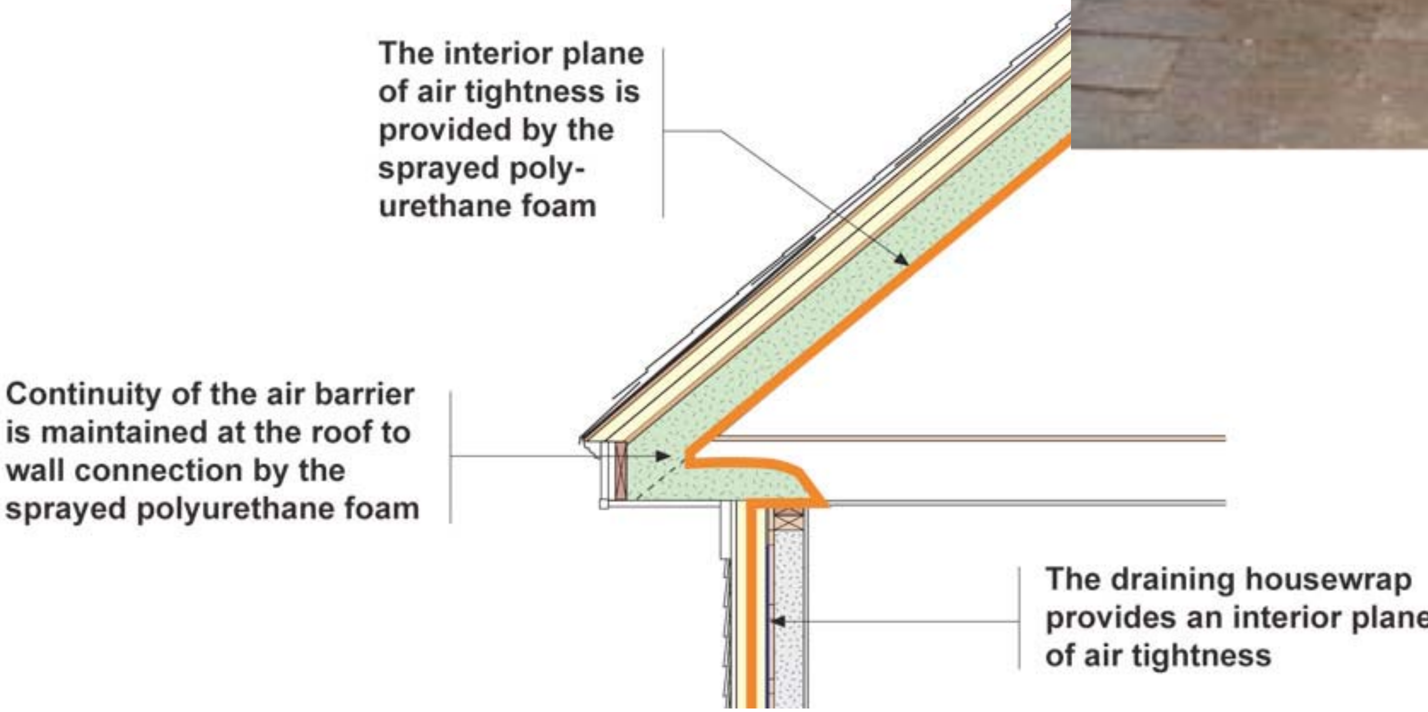


Air sealing	None	Retrofitted air barrier: spray polyurethane foam (basement, attic roofdeck, connections between components) and corrugated housewrap at above grade walls. Low expanding foam sealant around windows
Space heating	Original Oil Fired Boiler Circa 1916	92% AFUE sealed combustion low mass 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/5694 kWh (modeled) 670 therms/3865 kWh (utility bills)

Air Barrier Continuity

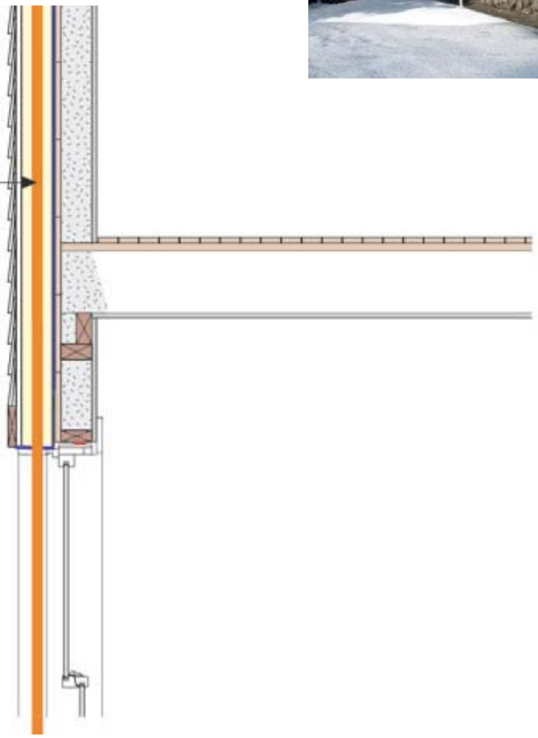


Air Barrier Continuity

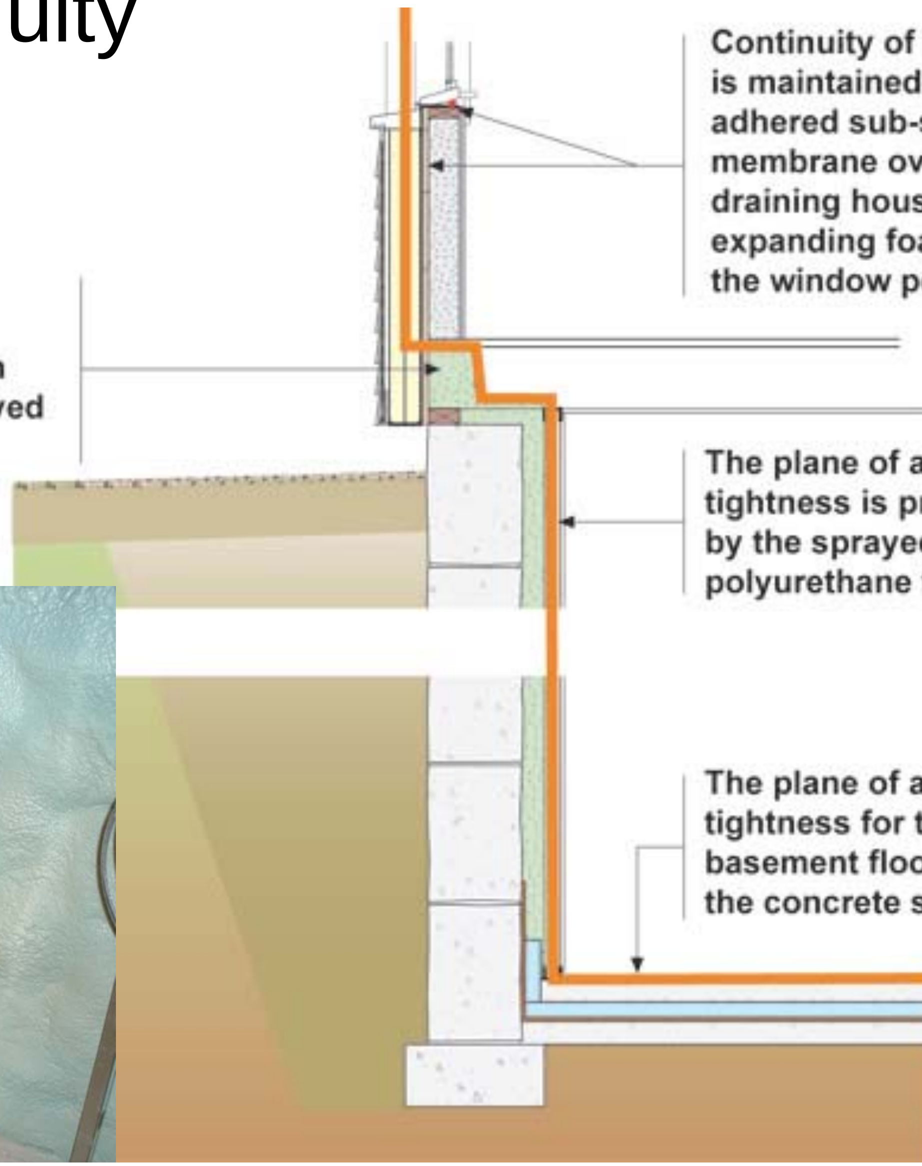


Air Barrier Continuity

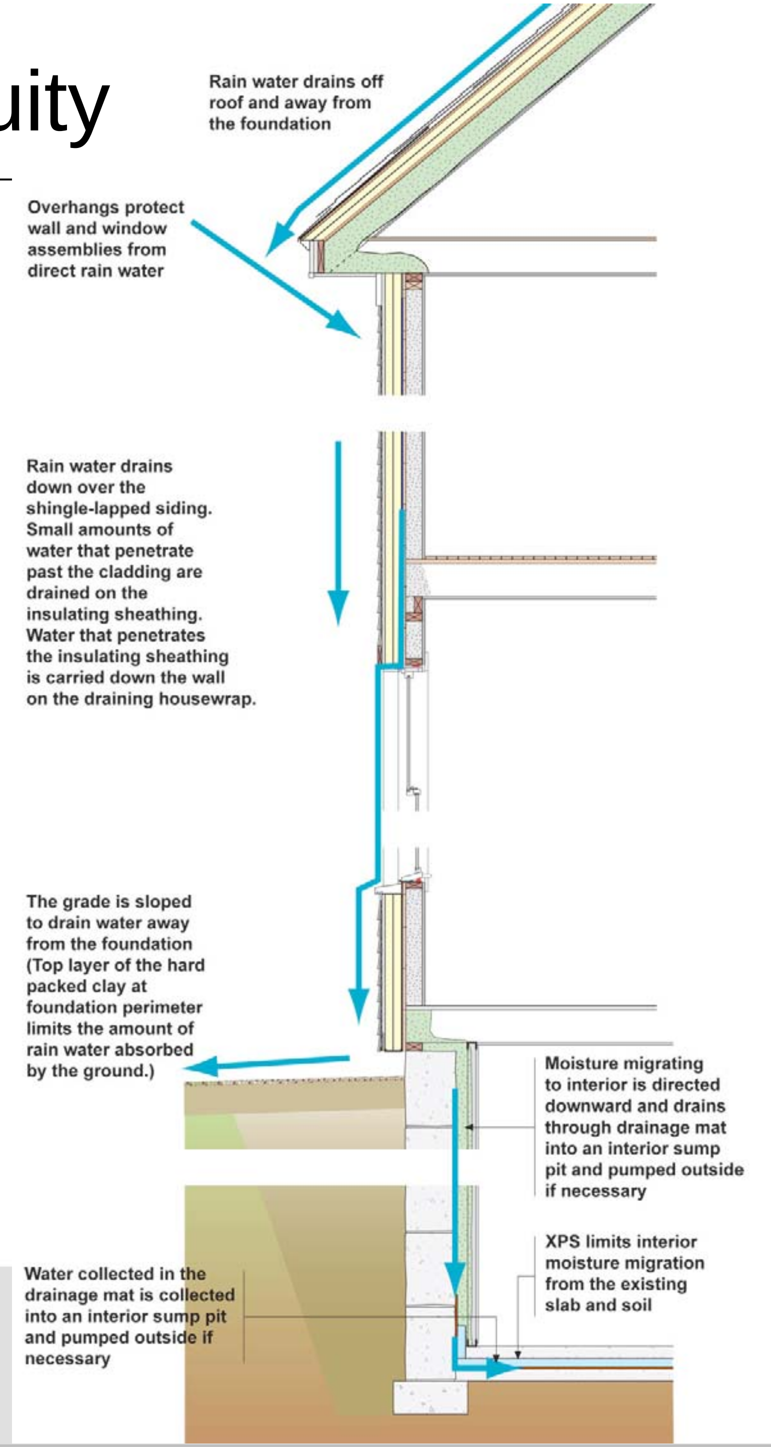
The taped and sealed exterior rigid insulation provides an exterior plane of air tightness to minimize the effects of wind washing of the insulation



Air Barrier Continuity



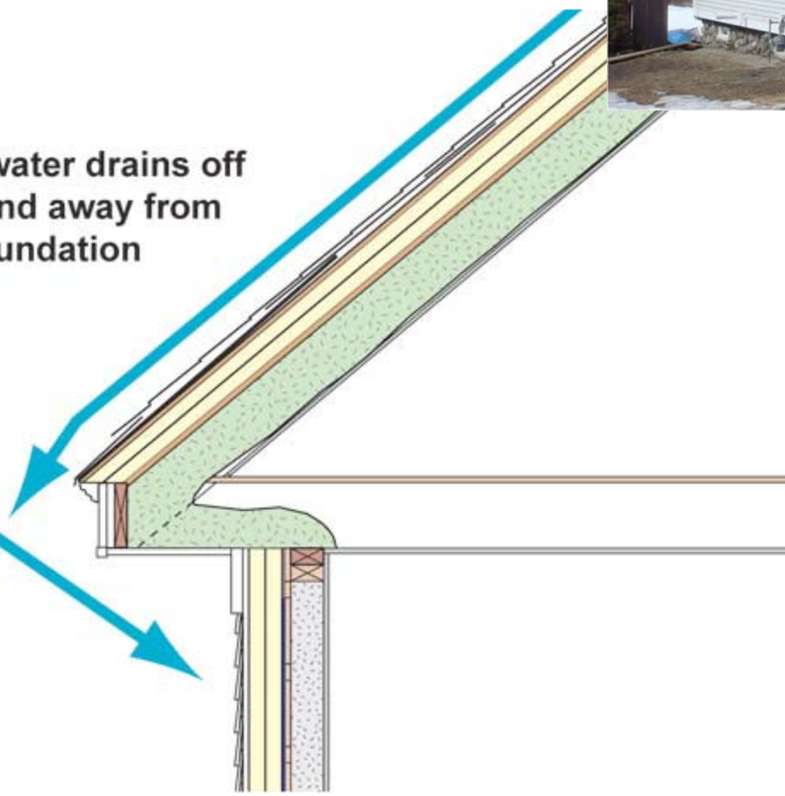
Drainage Plane Continuity



Drainage Plane Continuity

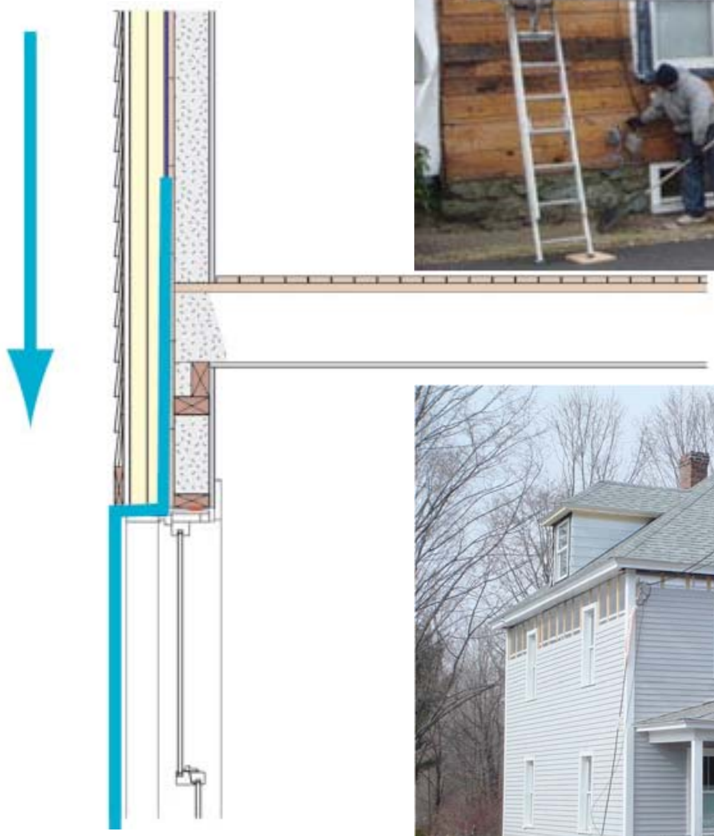
Rain water drains off roof and away from the foundation

Overhangs protect wall and window assemblies from direct rain water



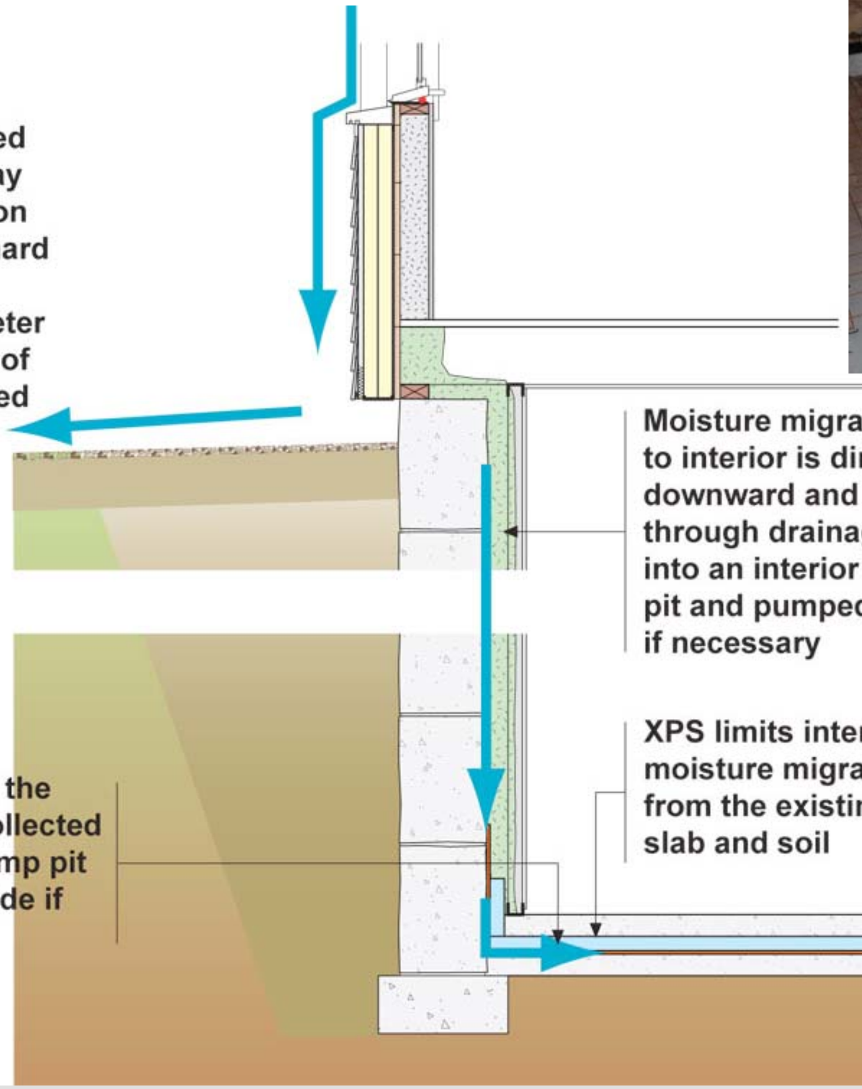
Drainage Plane Continuity

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.




Tyvek

Drainage Plane Continuity



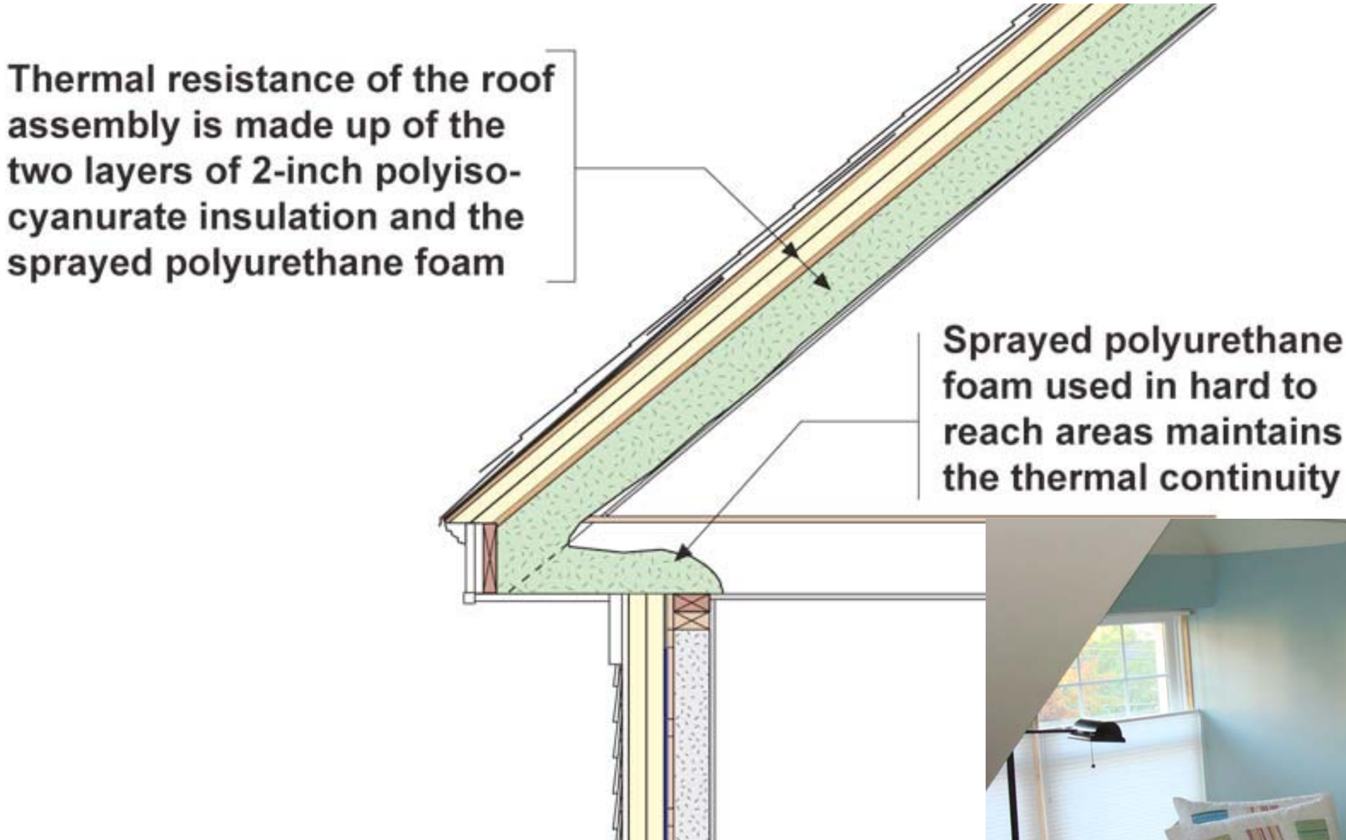
The grade is sloped to drain water away from the foundation (Top layer of the hard packed clay at foundation perimeter limits the amount of rain water absorbed by the ground.)

Moisture migrating to interior is directed downward and drains through drainage mat into an interior sump pit and pumped outside if necessary

XPS limits interior moisture migration from the existing slab and soil

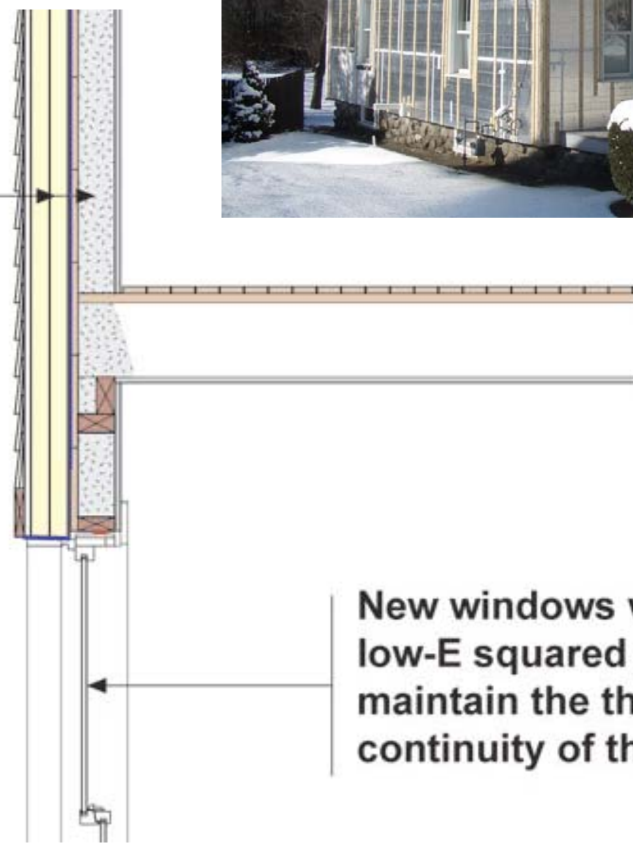
Water collected in the drainage mat is collected into an interior sump pit and pumped outside if necessary

Thermal Continuity



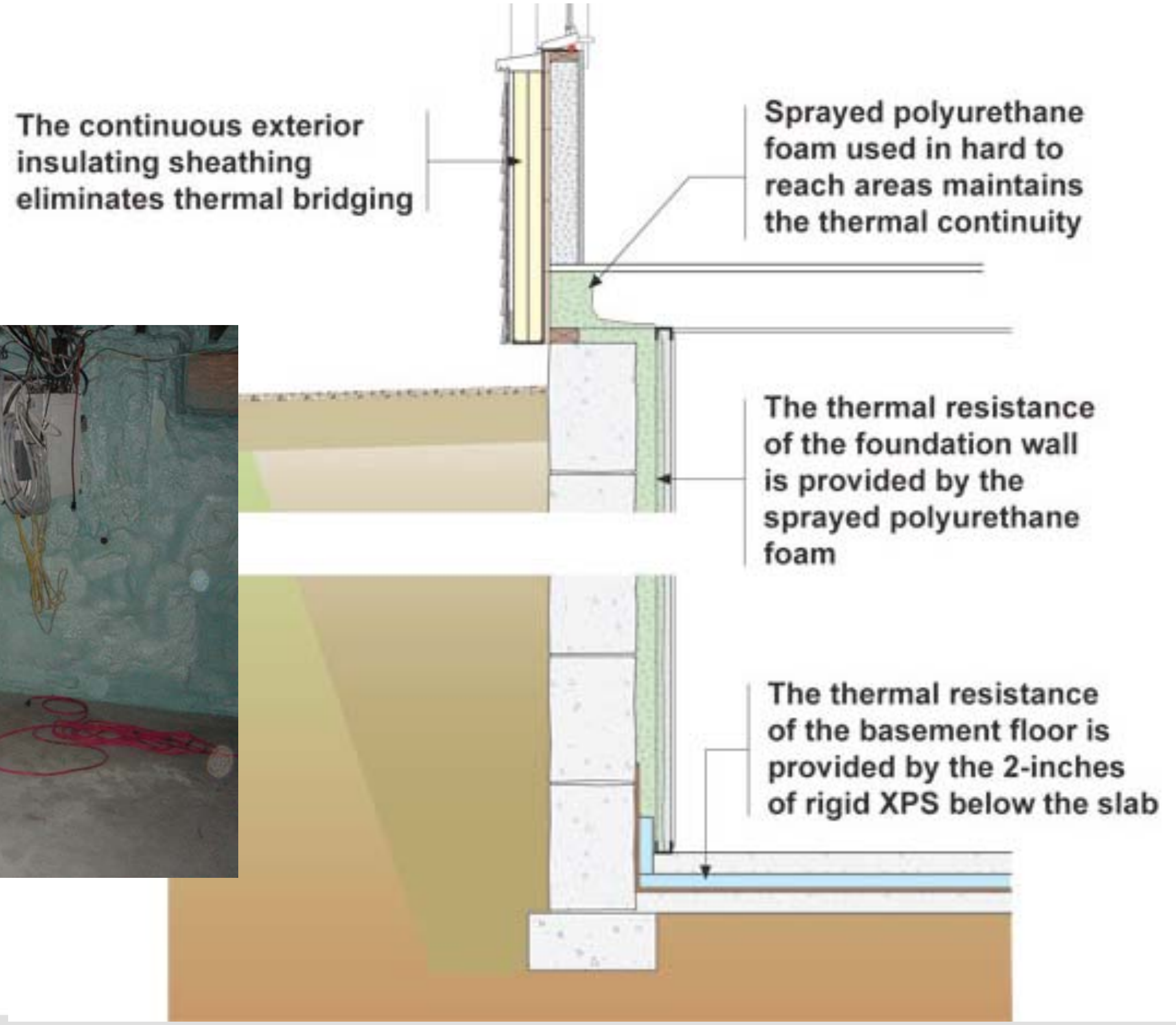
Thermal Continuity

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

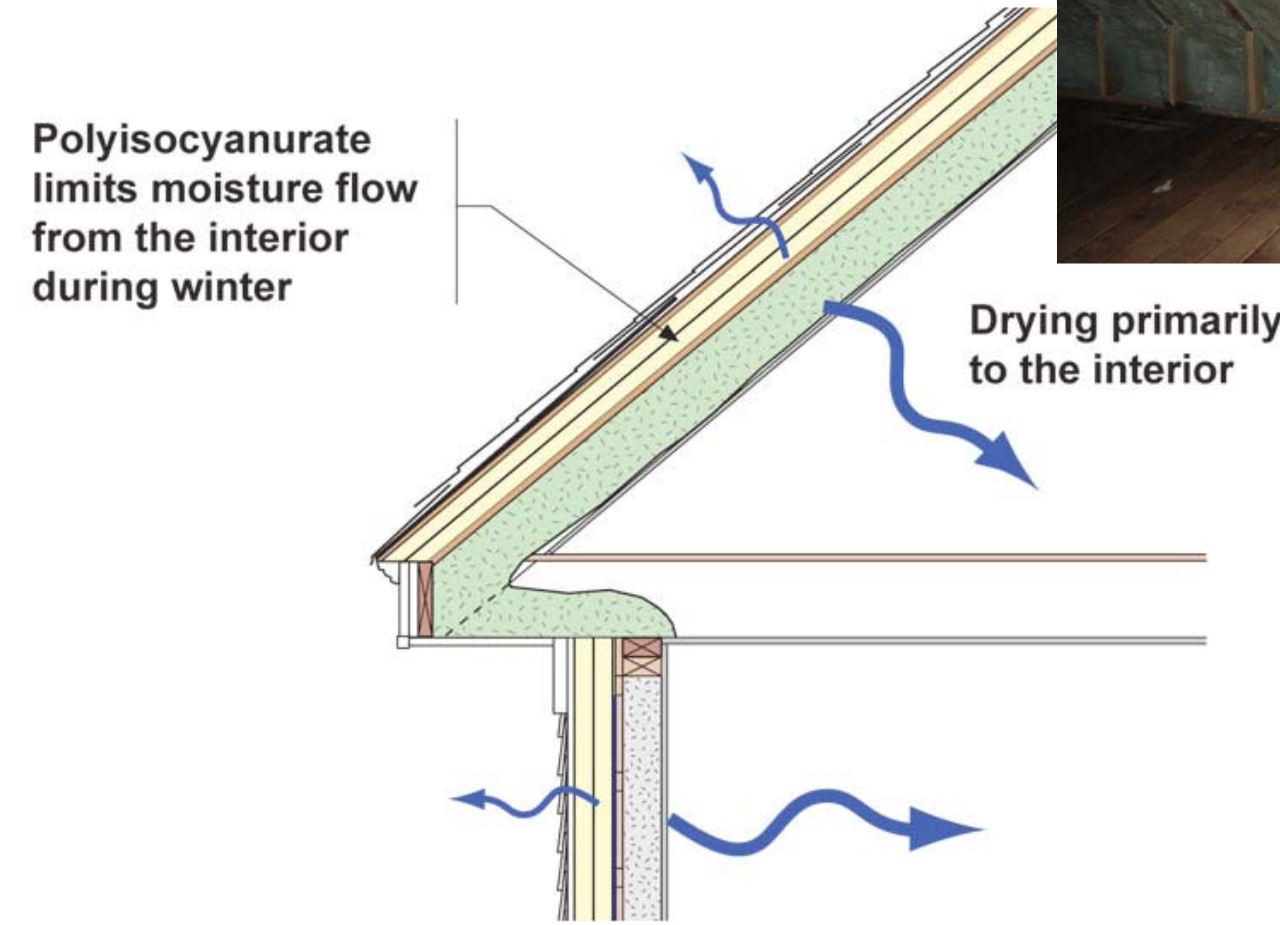


New windows with low-E squared glazing maintain the thermal continuity of the wall

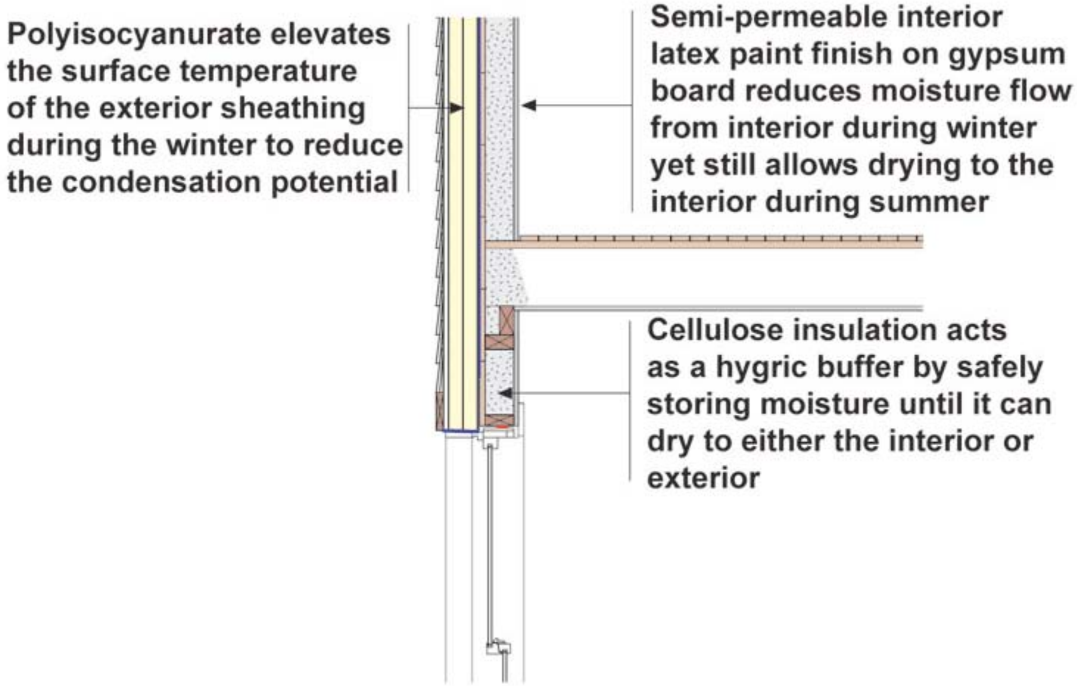
Thermal Continuity



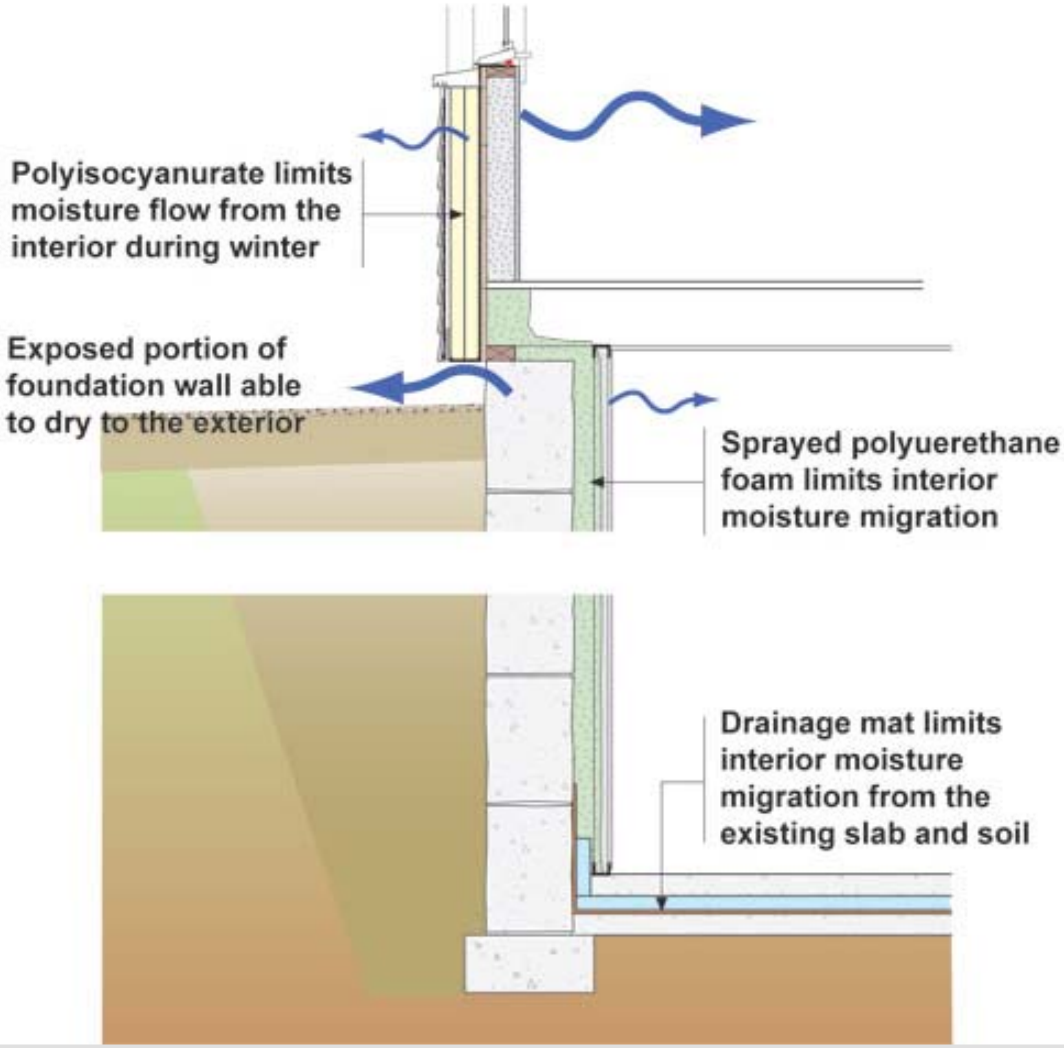
Vapor Barrier Continuity



Vapor Barrier Continuity



Vapor Barrier Continuity

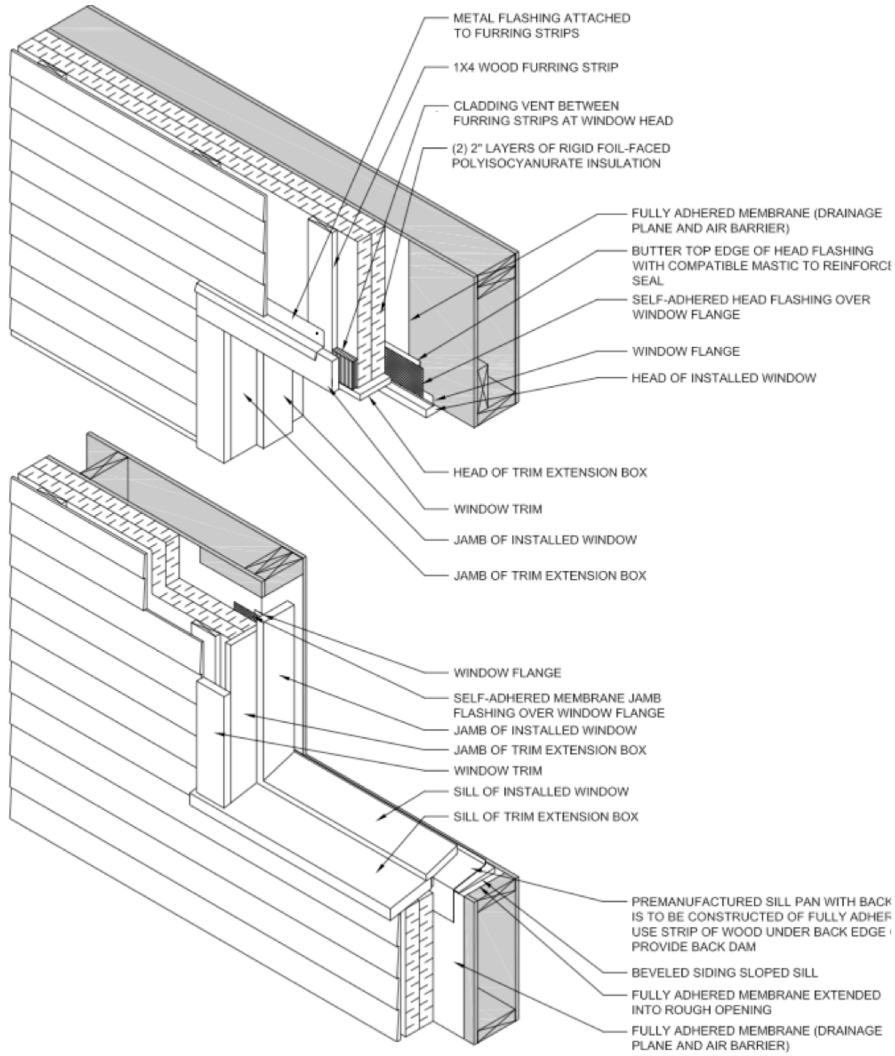


New Windows

Photos courtesy of Dan Morrison, *Fine Homebuilding Magazine*

New Windows

Windows



METAL FLASHING ATTACHED TO FURRING STRIPS
1X4 WOOD FURRING STRIP
CLADDING VENT BETWEEN FURRING STRIPS AT WINDOW HEAD
(2) 2" LAYERS OF RIGID FOIL-FACED POLYISOCYANURATE INSULATION
FULLY ADHERED MEMBRANE (DRAINAGE PLANE AND AIR BARRIER)
BUTTER TOP EDGE OF HEAD FLASHING WITH COMPATIBLE MASTIC TO REINFORC SEAL
SELF-ADHERED HEAD FLASHING OVER WINDOW FLANGE
WINDOW FLANGE
HEAD OF INSTALLED WINDOW
HEAD OF TRIM EXTENSION BOX
WINDOW TRIM
JAMB OF INSTALLED WINDOW
JAMB OF TRIM EXTENSION BOX
WINDOW FLANGE
SELF-ADHERED MEMBRANE JAMB FLASHING OVER WINDOW FLANGE
JAMB OF INSTALLED WINDOW
JAMB OF TRIM EXTENSION BOX
WINDOW TRIM
SILL OF INSTALLED WINDOW
SILL OF TRIM EXTENSION BOX
PREMANUFACTURED SILL PAN WITH BACK IS TO BE CONSTRUCTED OF FULLY ADHER USE STRIP OF WOOD UNDER BACK EDGE PROVIDE BACK DAM
BEVELED SIDING SLOPED SILL
FULLY ADHERED MEMBRANE EXTENDED INTO ROUGH OPENING
FULLY ADHERED MEMBRANE (DRAINAGE PLANE AND AIR BARRIER)

Deep Energy Retrofit

First and Second Year Performance

3500 kWh and 700 Therms

Electric @ $.15 /kWh Gas @ $1.50/therm
Electric $528   Gas $1050
Electric/mth - $44 Gas/mth = $87

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

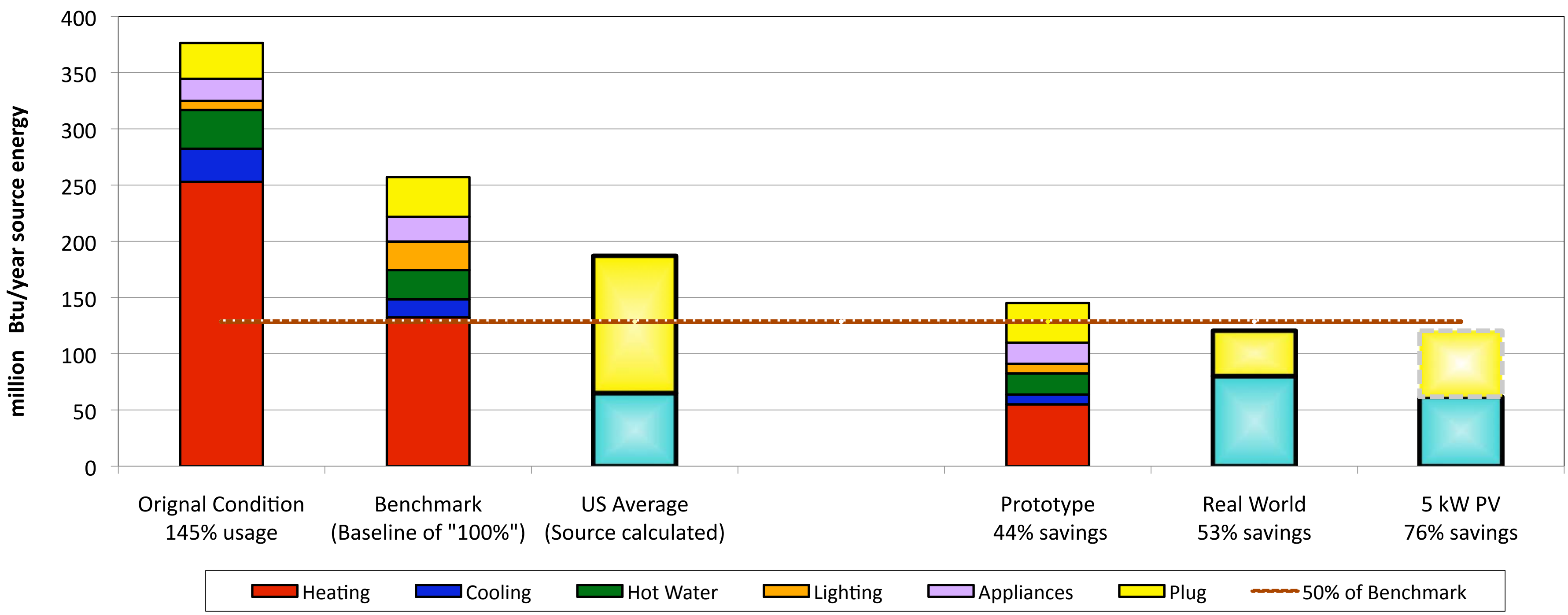
Initial Cost Of Measures	Annual Savings	Annual Finance 30 yrs @ 4.5%	Cash Flow
$70,000	$4005	$4248	($243)

Deep Energy Retrofit

Deep Energy Retrofit

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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Building America U.S. Department of Energy

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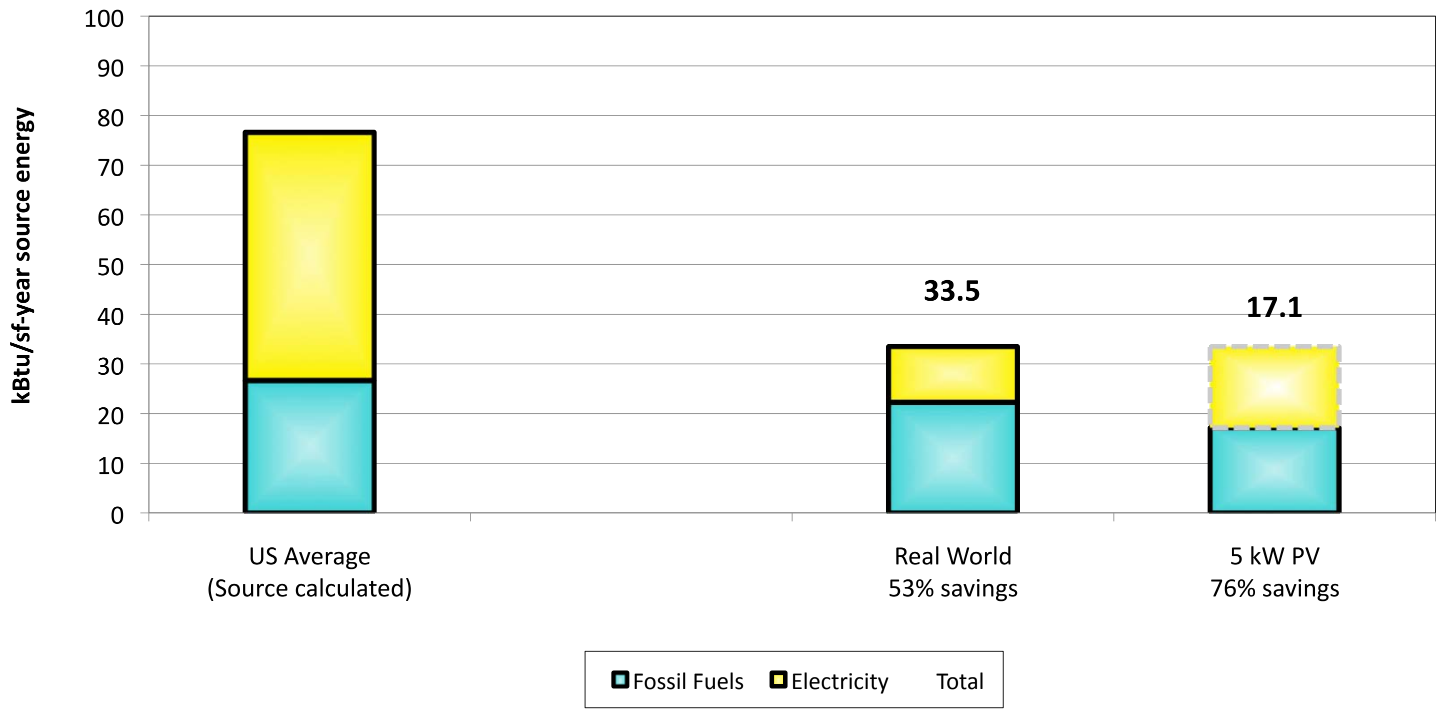
Deep Energy Retrofit

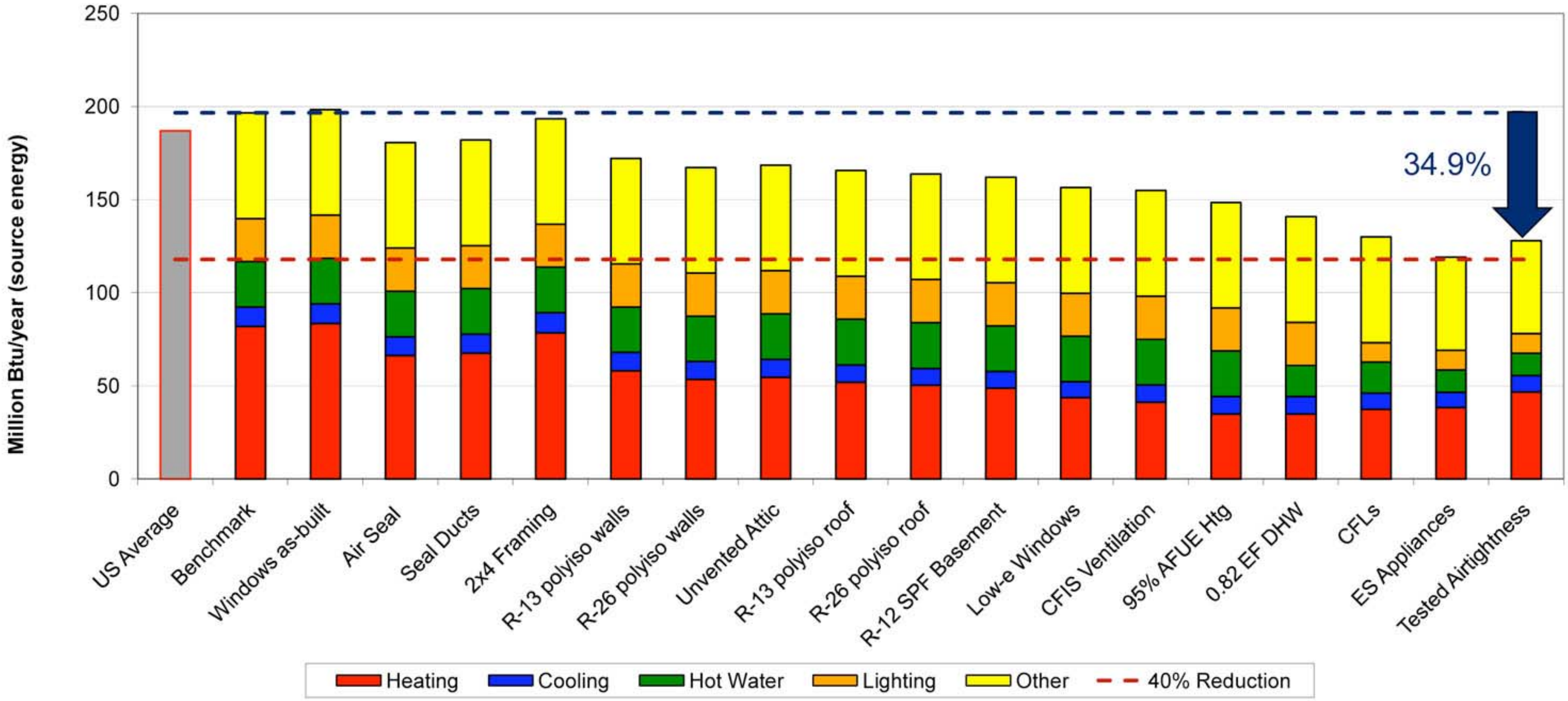
METRICS

- Total Energy Use is 62 MMBtu's source. National average is 190 MMBtu's source.
- Total conditioned square ft = 3600. kBtu's per sq. ft. before PV's = 33.5
- With the PV's, kBtu's per sq. ft. = 17.1

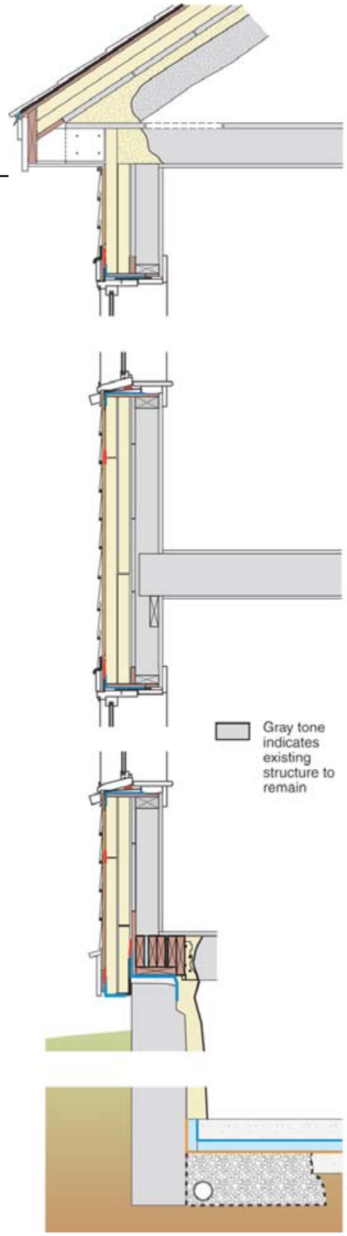


Lowell HFH Farmhouse, Bedford - MA

Parametric Study



Building Profile



Roof Assembly

Wall Assembly

Windows

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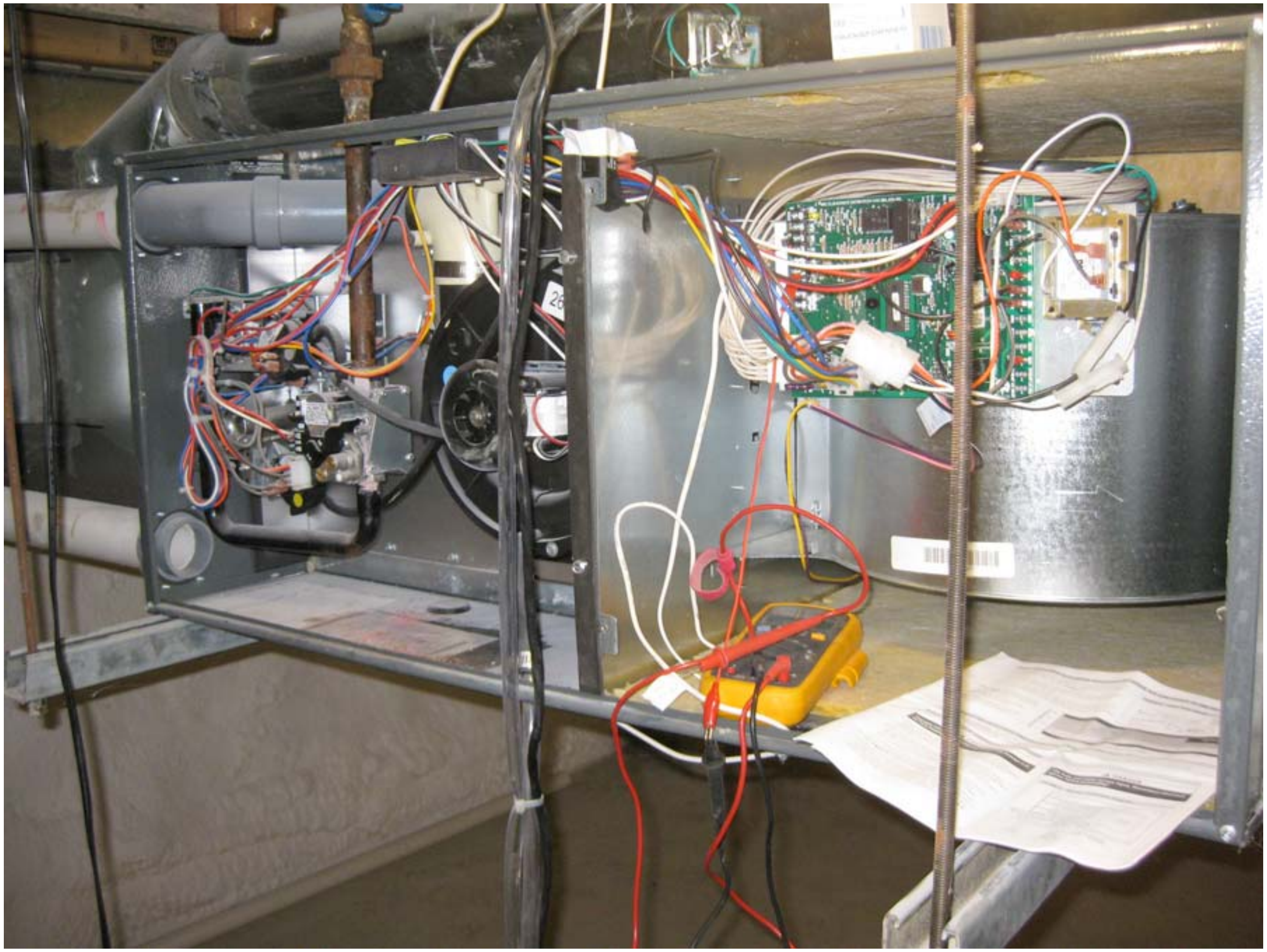
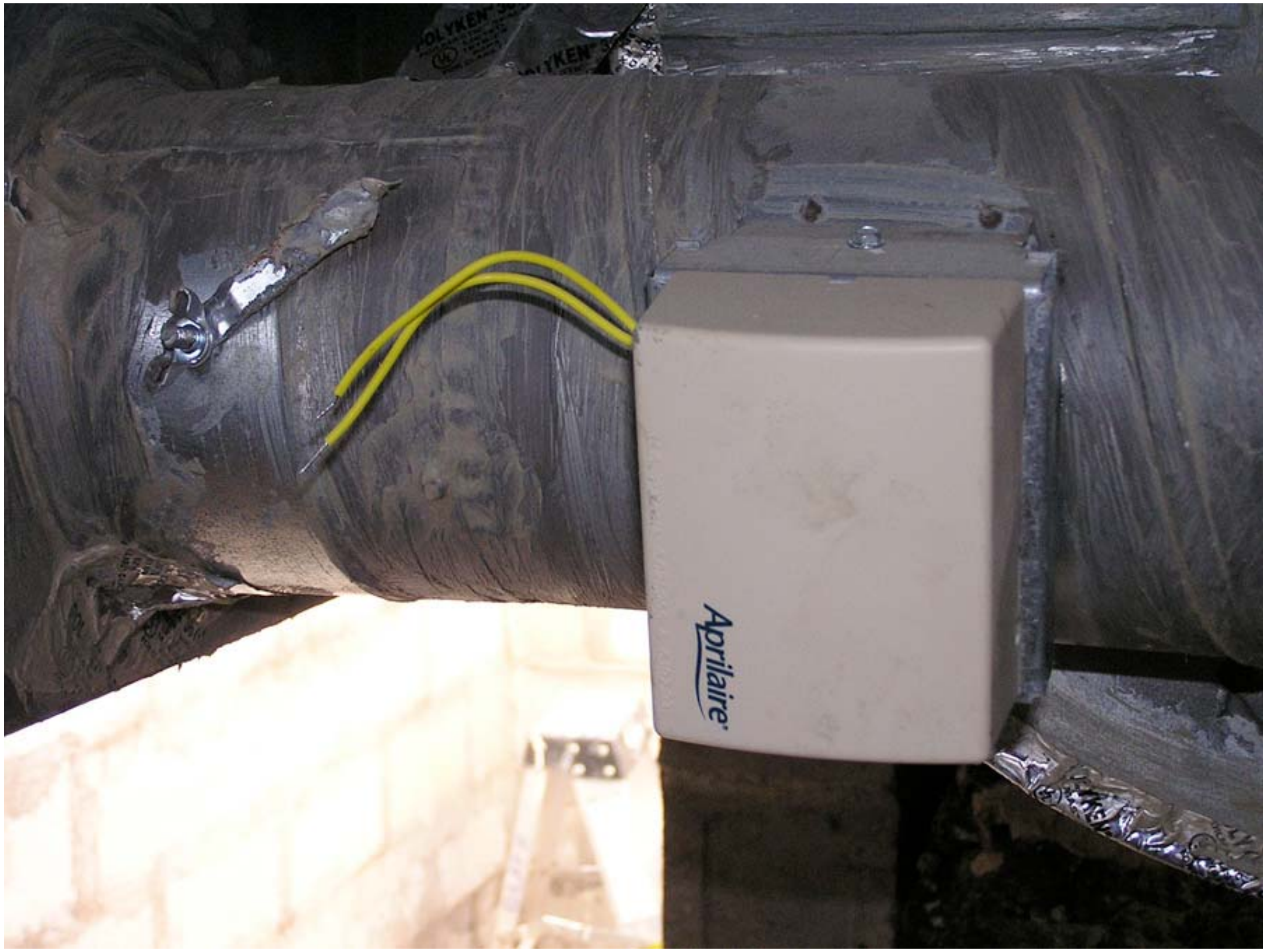
Air Sealing

Foundation Assembly

Sealed Combustion Gas Furnace



Ventilation



Space Conditioning Distribution

On-Demand Gas Water Heater

Lighting

Appliances

Rim joist

Window sill dam

Duct blaster testing

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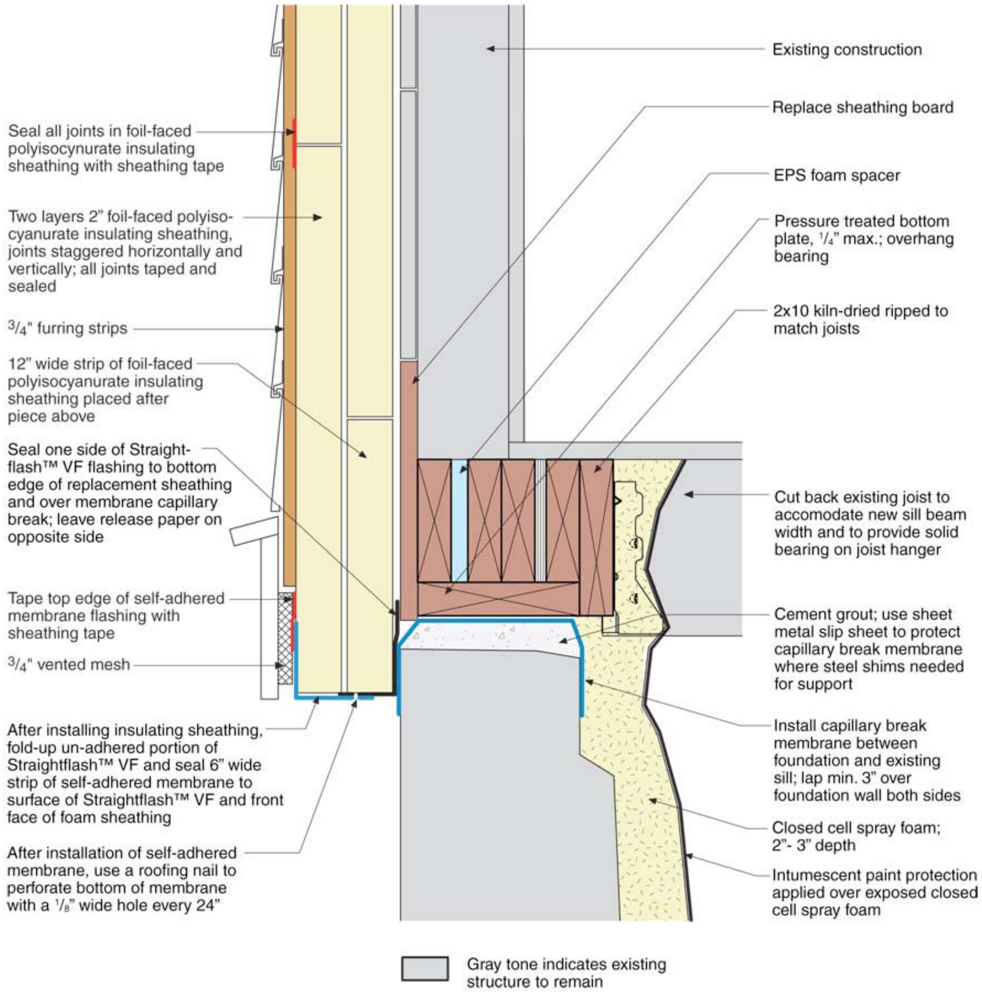
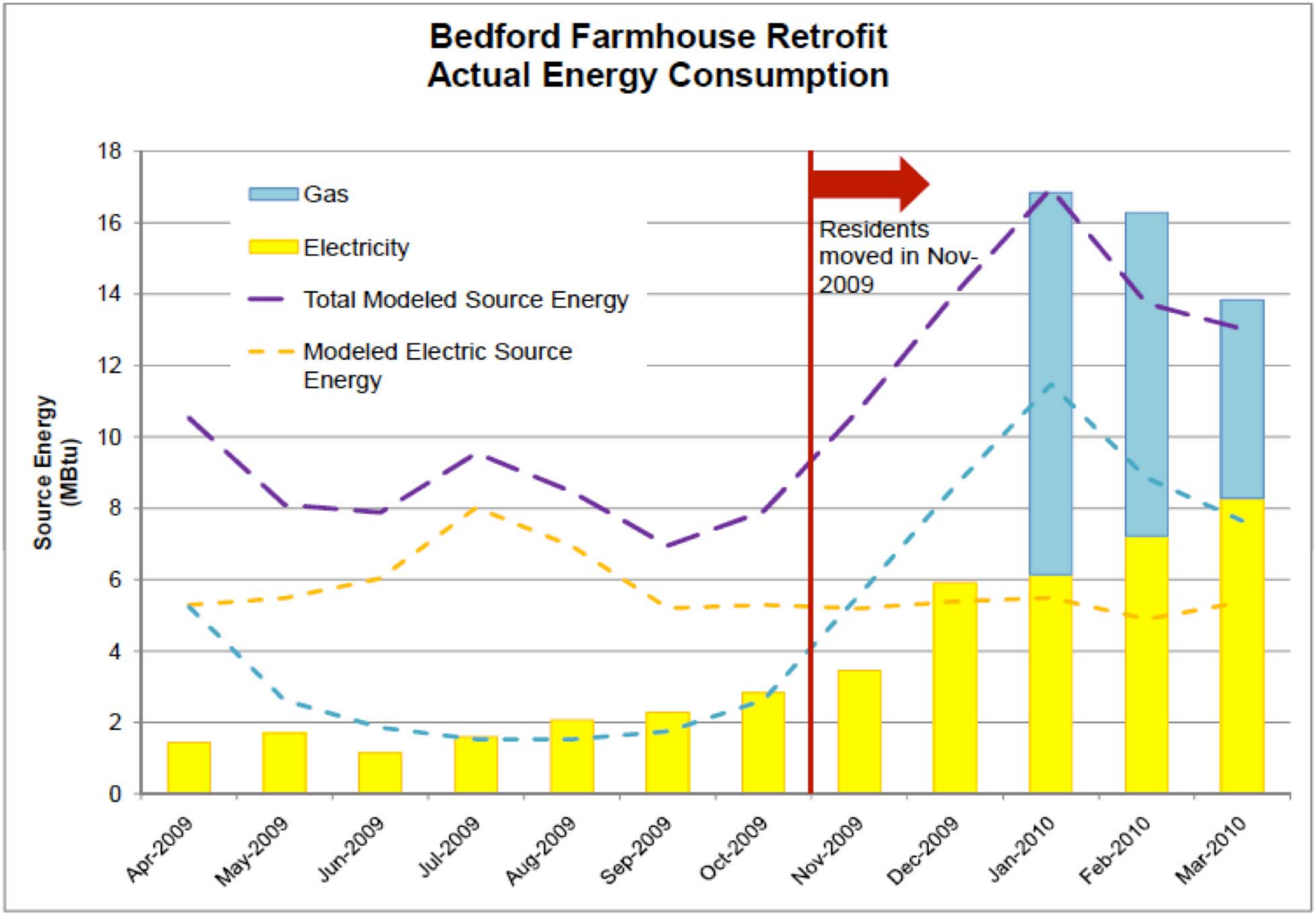
Air Leakage Control



Air Leakage Control

Air Leakage Control

Air Leakage Control


Bedford Farmhouse Retrofit
Actual Energy Consumption
Source Energy (MBtu)
0
2
4
6
8
10
12
14
16
18
Gas
Electricity
Total Modeled Source Energy
Modeled Electric Source Energy
Residents moved in Nov-2009
Apr-2009
May-2009
Jun-2009
Jul-2009
Aug-2009
Sep-2009
Oct-2009
Nov-2009
Dec-2009
Jan-2010
Feb-2010
Mar-2010

Freeport Retrofit

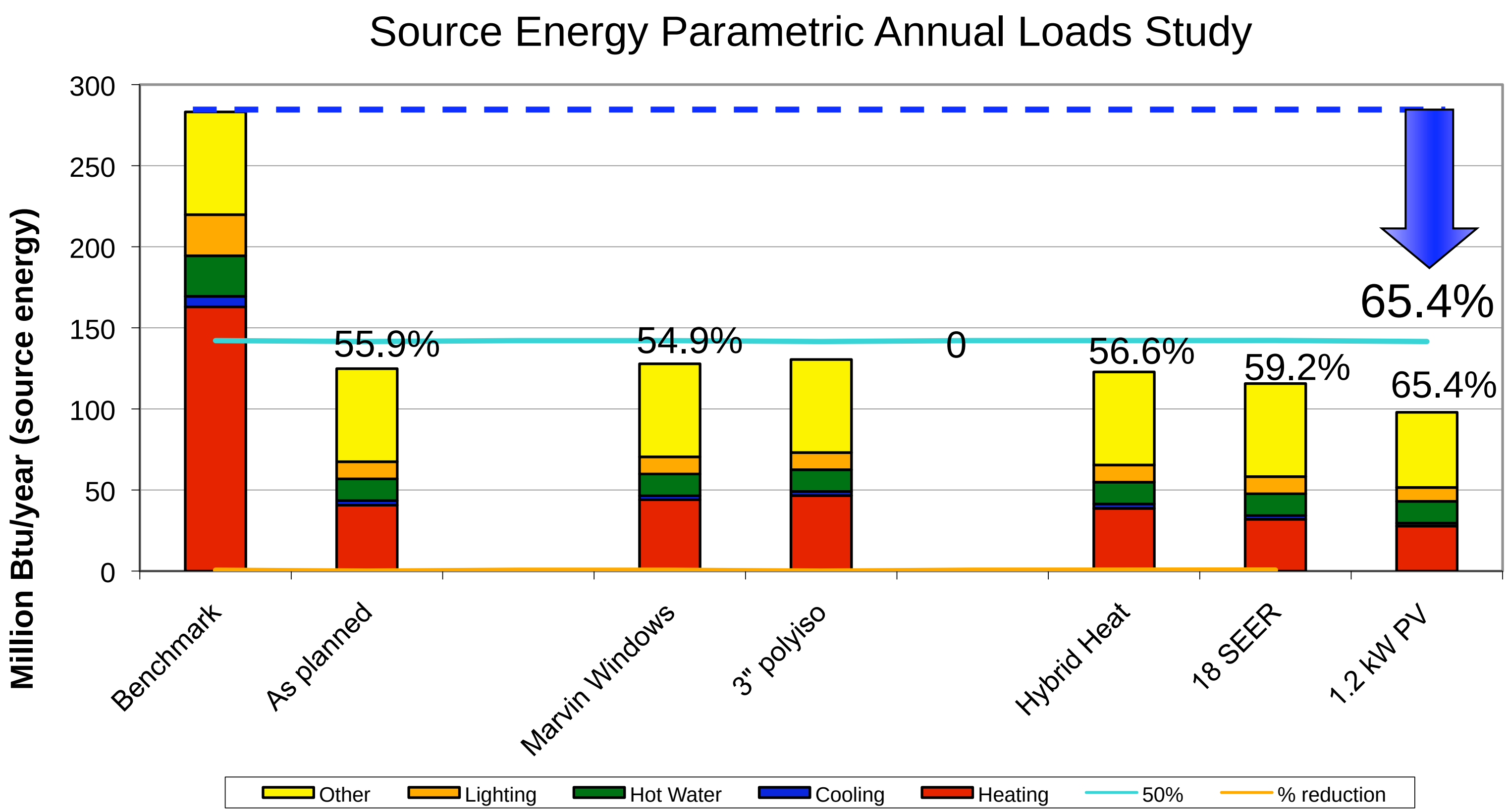
57 Depot Street prior to construction

Freeport Retrofit

- Project Overview
  - Builder: Warren Construction Group
  - Location: Freeport, ME
  - Climate: Cold (6A)
  - Type: Single Family
  - Stories: 2
  - Bedrooms: 3
  - Baths: 1.5
  - Floor Area: 1,600 sq.ft.
  - Basement Area: 886 sq.ft.

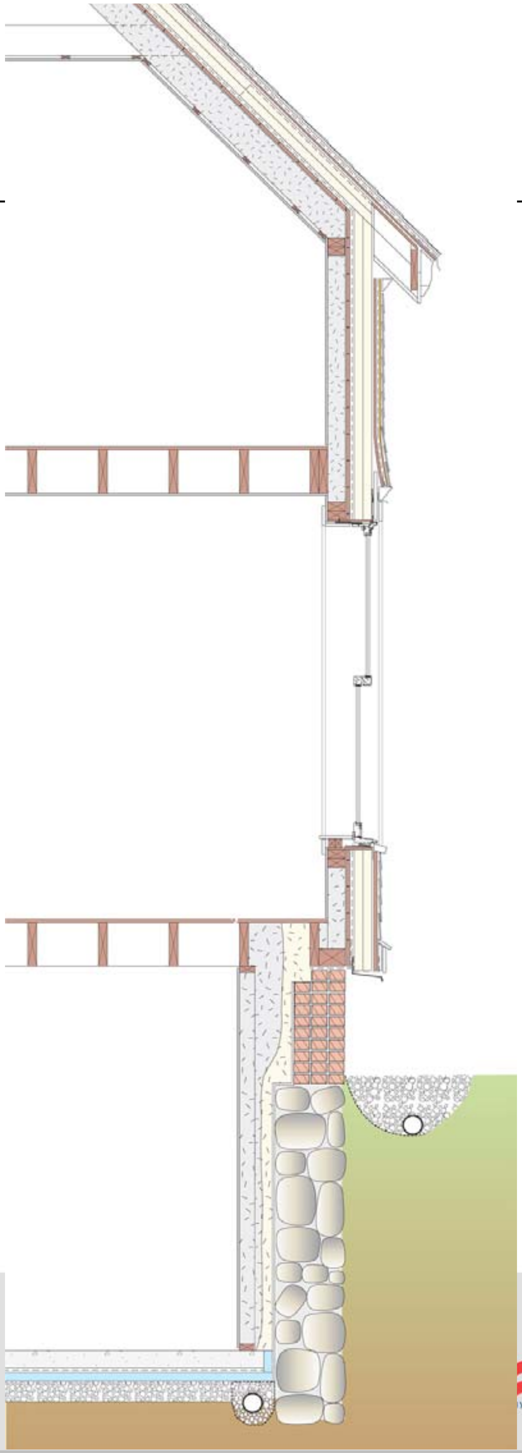
Freeport Retrofit

- Source Energy Savings



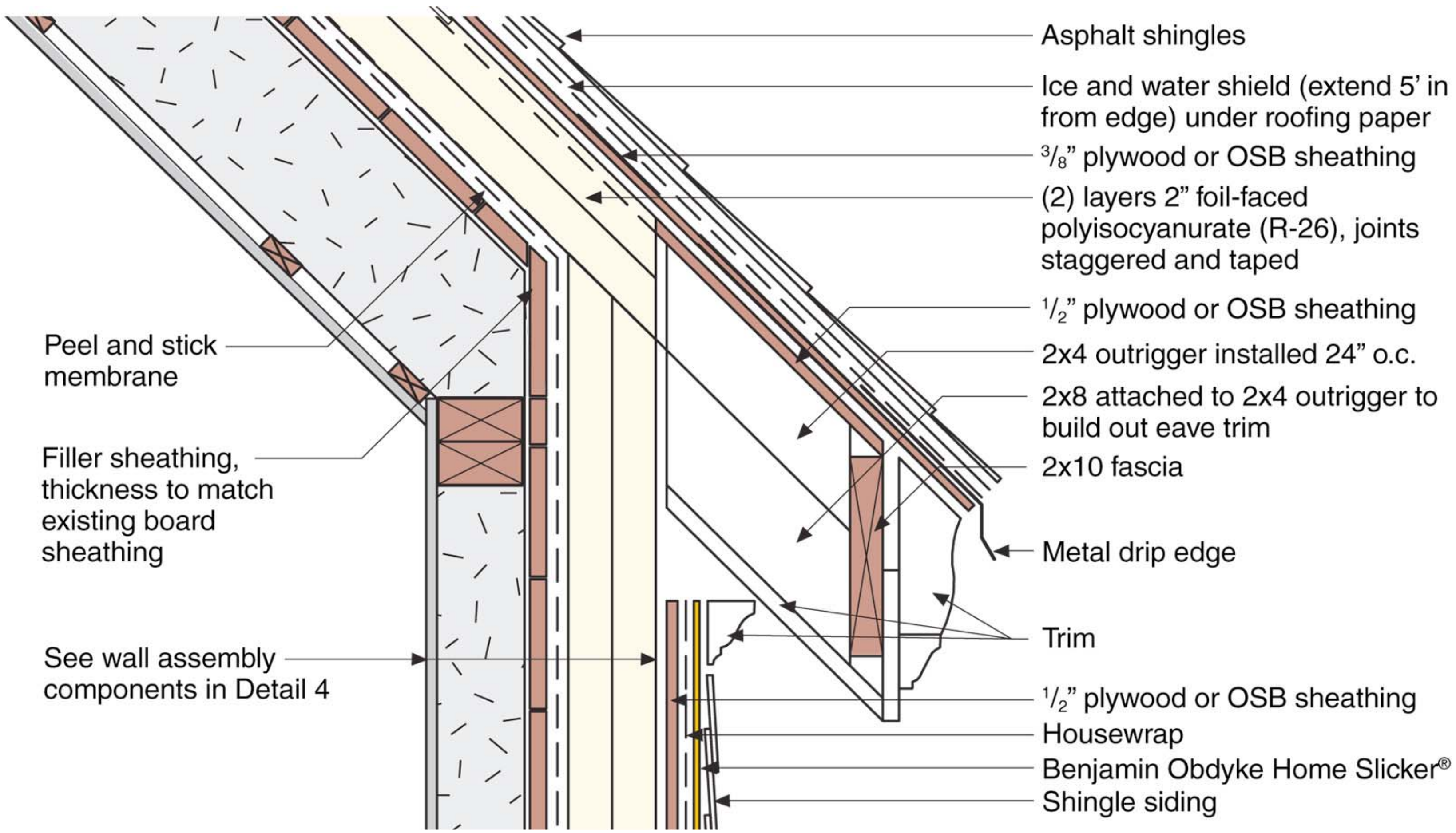
Freeport Retrofit

- Wall Section



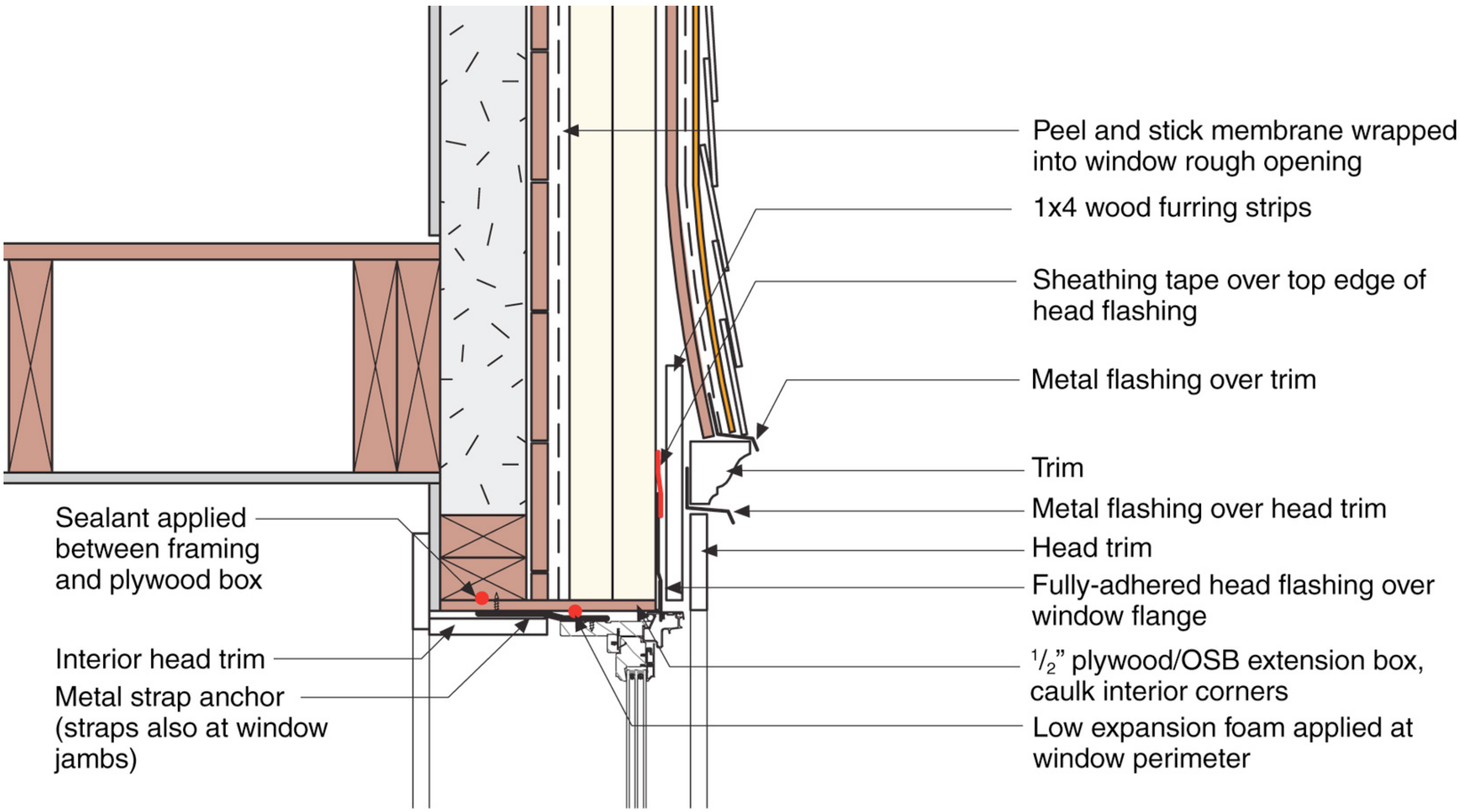
Freeport Retrofit

- Roof R-50



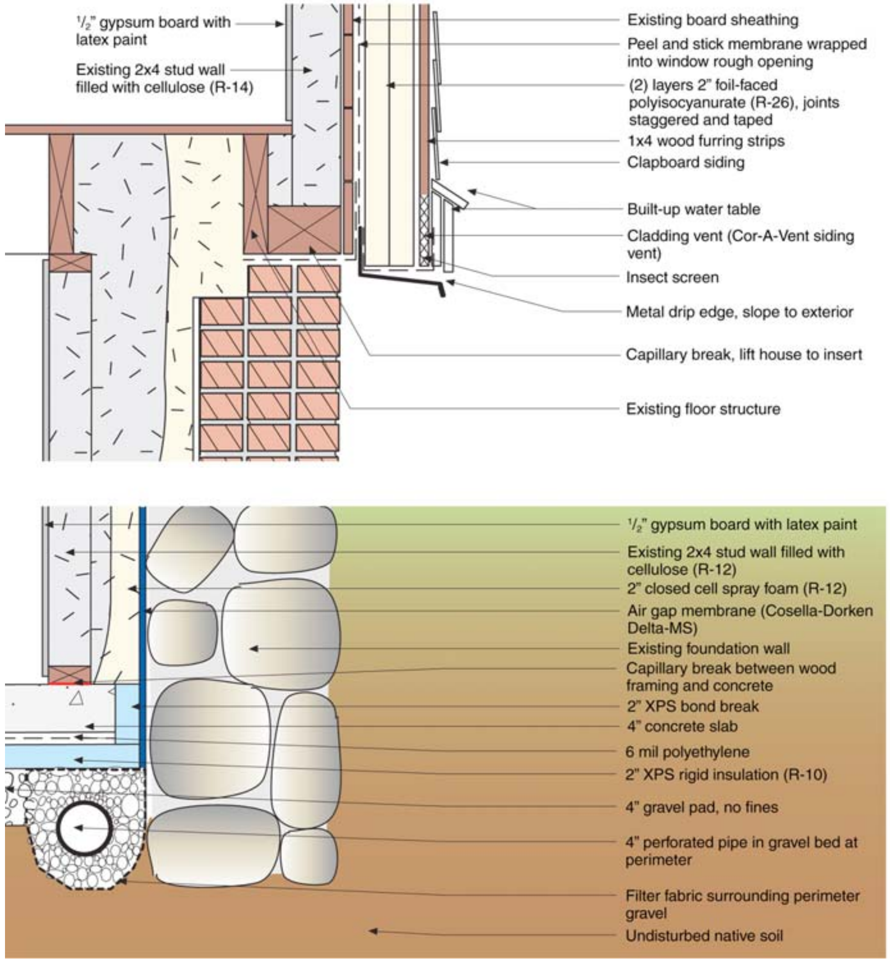
Freeport Retrofit

- Wall R-40 Windows R-5

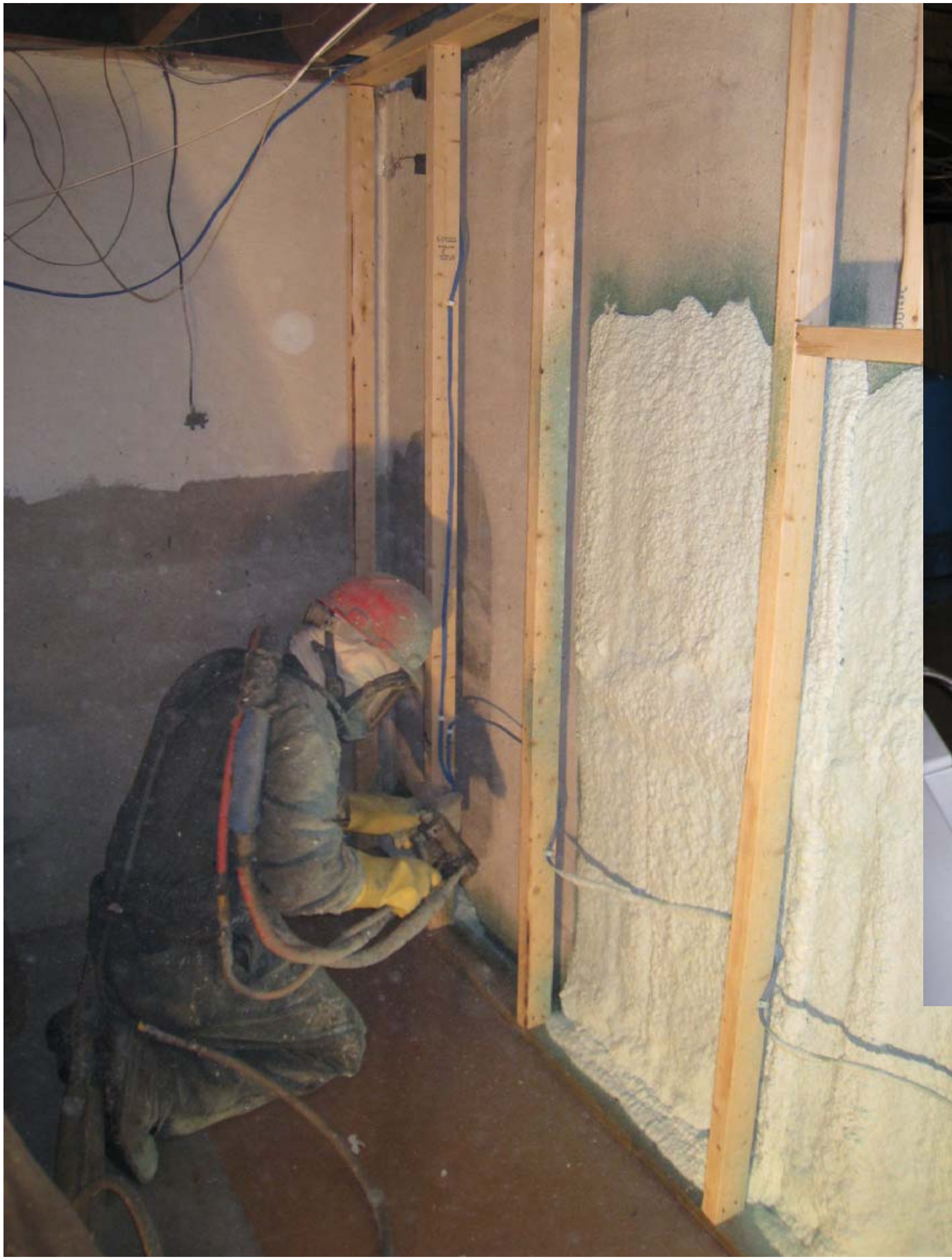


Freeport Retrofit

- Foundation, Slab R-10, Walls R-12



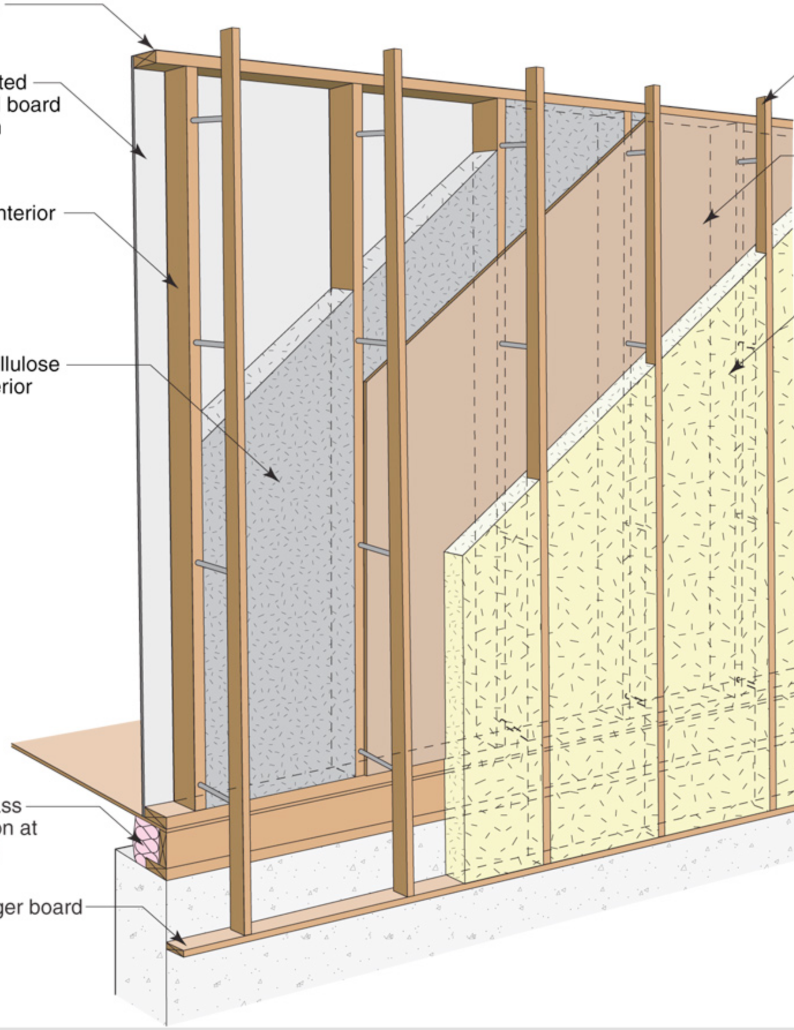
Berletts Road House, Waterloo - Ontario


Above Grade Walls

- Interior retrofit limits improvements to airtightness, rain control,thermal bridge
- Exterior allows excellent improvements and increased durability
- Windows should be done at the same time
- Installation cost $200+/- so get good windows, eg vinyl triple glazed for $30/sf

Above Grade Walls



Above Grade Walls

Windows

- Important choice!
- Need better rain control
- Improved R-value of course


RIPCORD™
Split Release
On Demand


INSTALL THIS SIDE IN & THIS END UP

Above Grade Walls

Fully Vented Attics

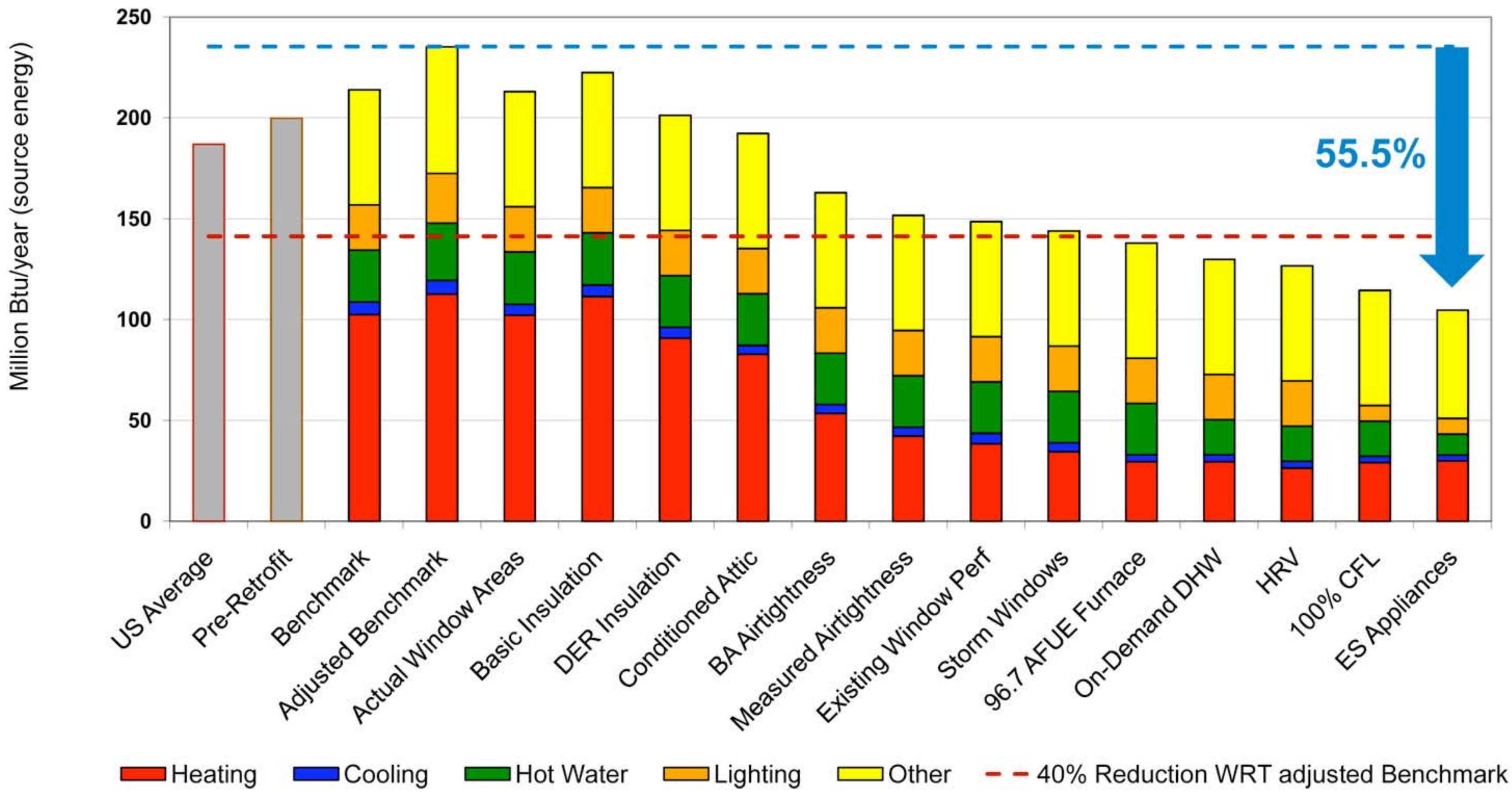
- Can re-roof whenever, with whatever
- Deal with moisture, then add insulation
  - Rain leaks, air leaks
- If possible, keep ventilated attic
  - Inspect ceiling plane, plug all holes with caulking and foam
  - Consider 1” of spray foam air barrier
  - Blow in minimum R60 cellulose, R75-R100 sensible

Energy/Economy

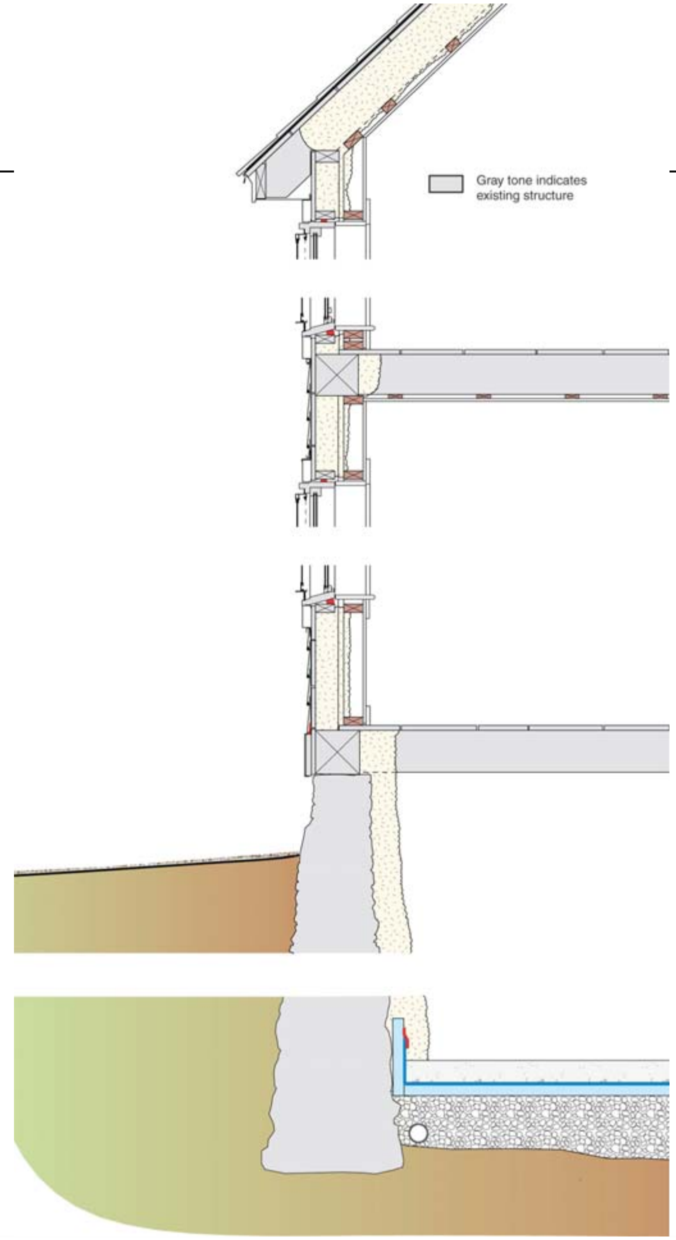
- Energy-related upgrades cost :$25K
  - Heat-pump, ducts, HRV $6000+2000+500
  - Basement/walls insulation $5200+4200
  - Windows $5000+ 2500
  - Attic $1250
- Many other upgrades: bed, bath, flooring, basement double floor space (another 30K)
- Savings: ca $2000 / yr

Clark Residence – Belchertown, MA

Parametric Study



Building Profile



Roof Assembly

Wall Assembly

Windows

Air Sealing

Foundation Assembly

Sealed Combustion Propane Furnace

Ventilation

Space Conditioning Distribution

On-Demand Propane Water Heater

Lighting

Appliances

Window installation

Soffit

Ceiling Deck

Duct blaster testing

Design Challenge

Design Challenge

For More Information Go To:

www.buildingscience.com

Search Info and Recent Presentations

www.affordablecomfort.org

See Thousand Home Challenge

www.powerofaction.com

National Grid's Deep Energy Retrofit Program