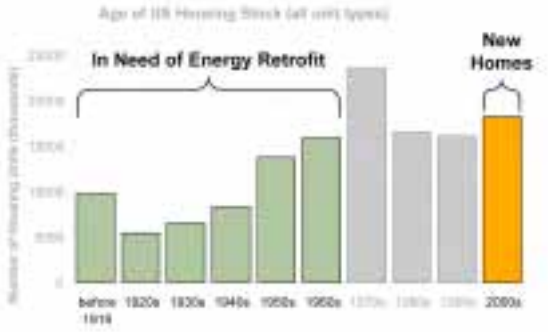
Deep Energy Retrofits of Single Family Homes

Betsy Pettit, FAIA
Building Science Corporation
www.buildingscience.com

EEBA Conference
Denver, CO September 29, 2009

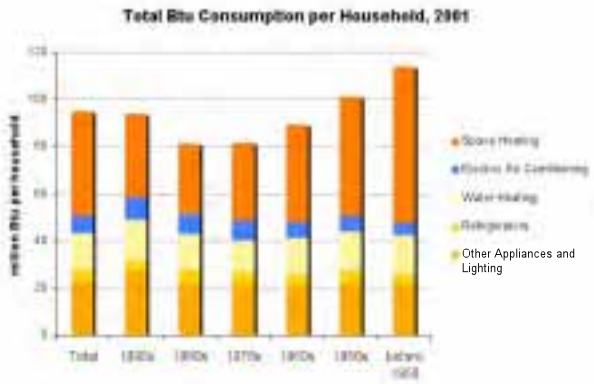
Existing Housing Stock

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

How Old and New Houses Use Energy

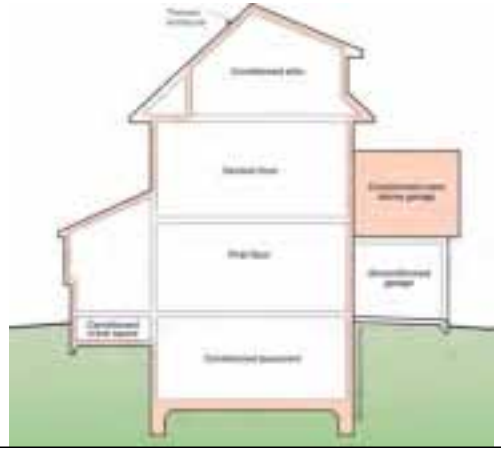


Source: US Census Bureau, Annual Housing Survey: http://www.census.gov/hhes/www/housing/ahs/ahs.html

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!

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

Enclosure Retrofit

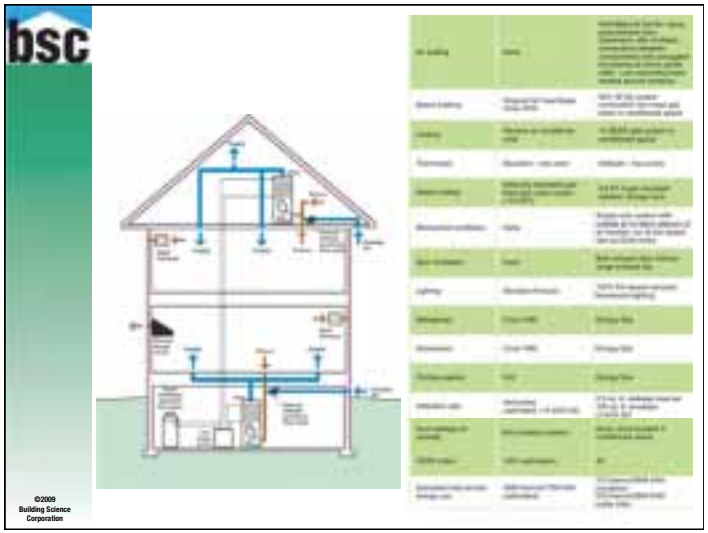
- Important target for many buildings
  - Airtightness
  - Windows
  - Insulation
    - Roof
    - Walls
    - Basement
    - Slabs
- Prioritize by Ease and Impact

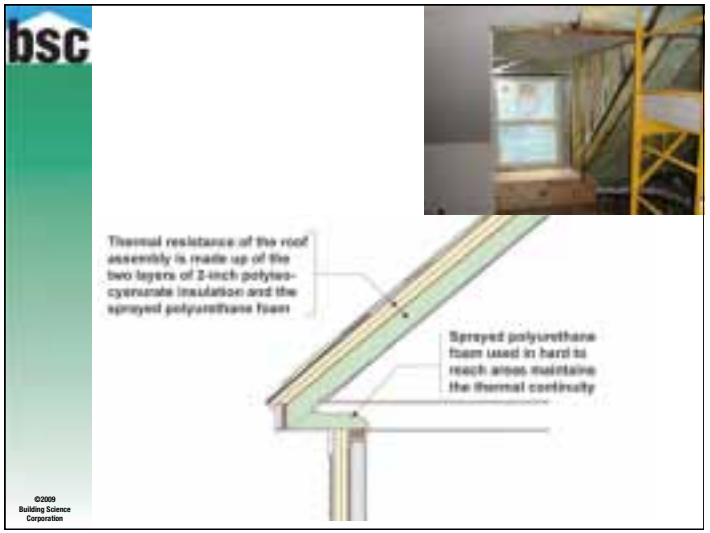
Deep Retrofit

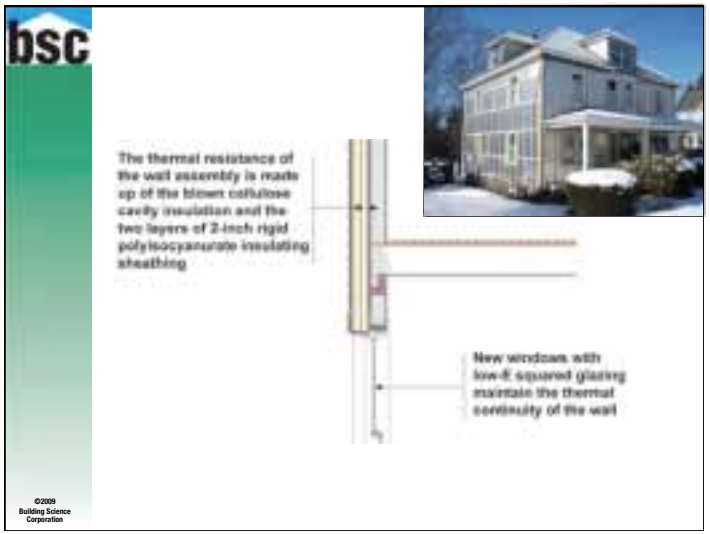
- Significant upgrades are incrementally less expensive
  - Small upgrades very cost effective, but small (10-25% reductions)
  - mid-range upgrades (15-50%) usually really expensive per energy saved
- Deep retrofits (>50%) secure buildings future
  - Allow for new styles, use, etc.
  - Leap frog current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

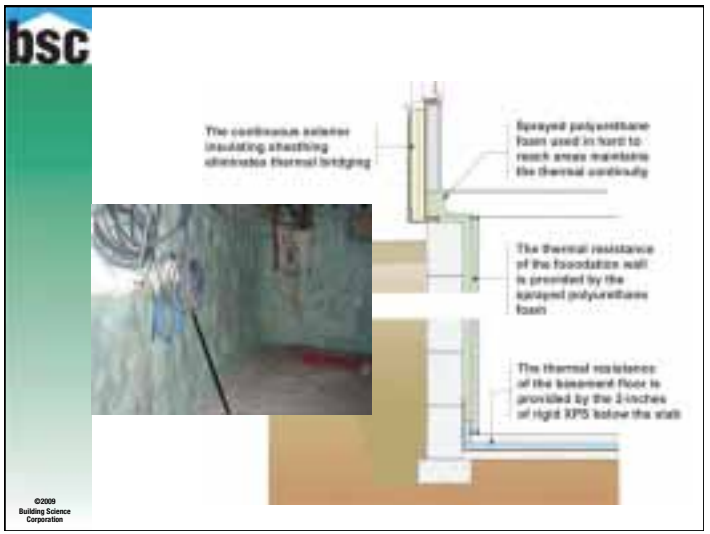
This Deep Energy Retrofit Reduced the Energy Consumption of the home by over 70%

The house is now ready for the next 100 years


bsc
©2009
Building Science
Corporation

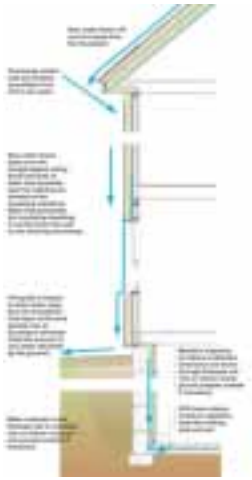

bsc
Thermal resistance of the roof assembly is made up of the two layers of 2-inch polyiso-cyanurate insulation and the sprayed polyurethane foam
Sprayed polyurethane foam used in hard to reach areas maintains the thermal continuity
©2009
Building Science
Corporation


bsc
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
©2009
Building Science
Corporation


bsc
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
©2009
Building Science
Corporation

Water Control Layer

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




bsc
©2009
Building Science
Corporation

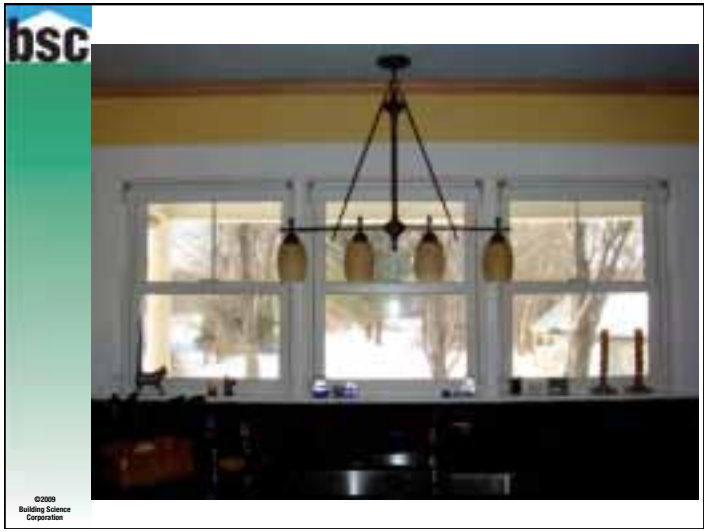

bsc
©2009
Building Science
Corporation


bsc
©2009
Building Science
Corporation


bsc
©2009
Building Science
Corporation


bsc
©2009
Building Science
Corporation


bsc
©2009
Building Science
Corporation


bsc
©2009
Building Science
Corporation


bsc
©2009
Building Science
Corporation


bsc
©2009
Building Science
Corporation


bsc
©2009
Building Science
Corporation


bsc
©2009
Building Science
Corporation


bsc
©2009
Building Science
Corporation


bsc
©2009
Building Science
Corporation


bsc
©2009
Building Science
Corporation


bsc
©2009
Building Science
Corporation


bsc
©2009
Building Science
Corporation


bsc
©2009
Building Science
Corporation


bsc
©2009
Building Science
Corporation


bsc
©2009
Building Science
Corporation


bsc
©2009
Building Science
Corporation

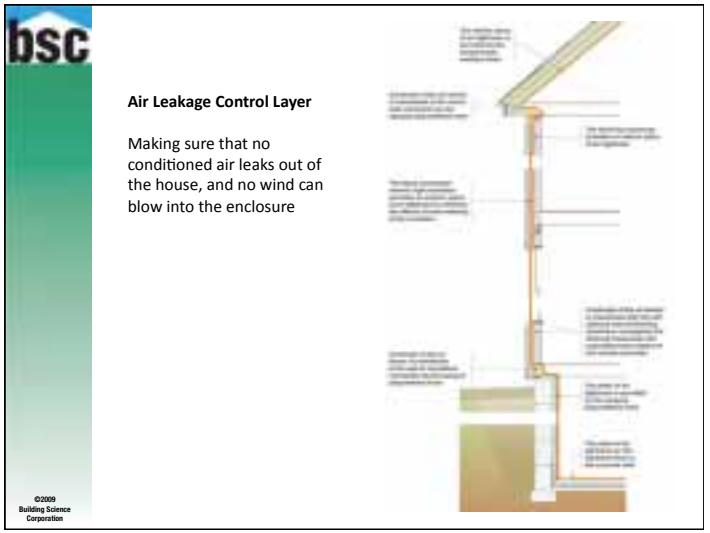

bsc
©2009
Building Science
Corporation


bsc
©2009
Building Science
Corporation


bsc
©2009
Building Science
Corporation


bsc
©2009
Building Science
Corporation


bsc
©2009
Building Science
Corporation

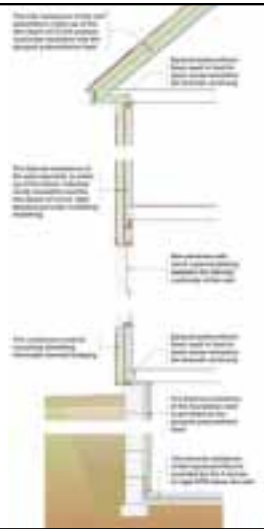

bsc
Air Leakage Control Layer
Making sure that no conditioned air leaks out of the house, and no wind can blow into the enclosure
©2009
Building Science
Corporation


bsc
©2009
Building Science
Corporation


bsc
©2009
Building Science
Corporation

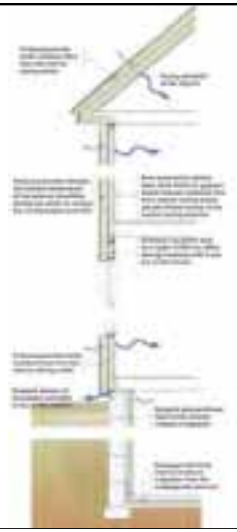
Thermal Control Layer

Must be consistent around all six sides of the cube



Vapor Control Layer

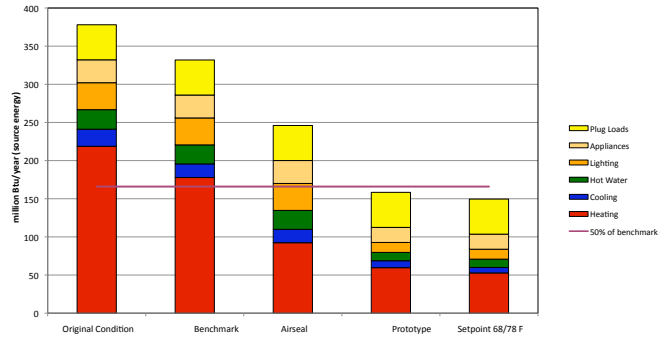
Make sure that no water in the vapor form gets trapped in assemblies, such that it gets cold enough to condense, turning to liquid water. When this happens things rot, corrode, and environments that are conducive to mold growth are created.

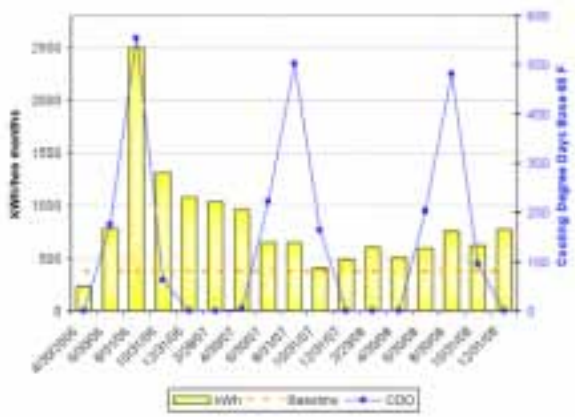


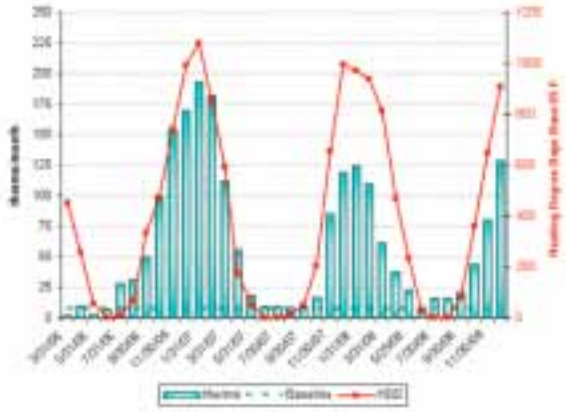
Old Boiler to New Boiler plus air handlers, outside air intake, filtration, and exhaust at baths and kitchen

Simulated Improvement Results from Original Condition

(Original Condition > HERS 150







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)

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)

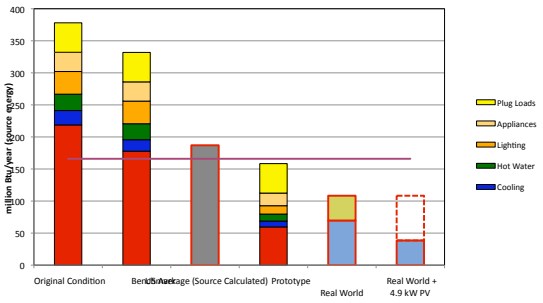
Adding Photovoltaic

•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)

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.



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

67

68

Farmhouse Retrofit

Bedford, MA

Habitat for Humanity of Greater Lowell

Farmhouse Retrofit

Bedford, MA

Habitat for Humanity of Greater Lowell

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

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

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

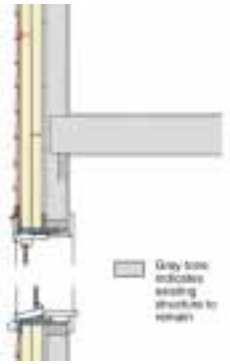
73

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



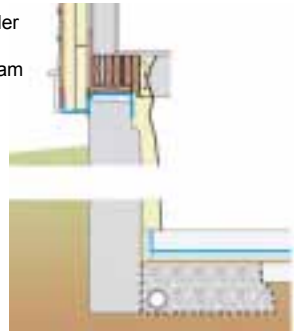
Typical Wall Section

74

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

- Window installation

- 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

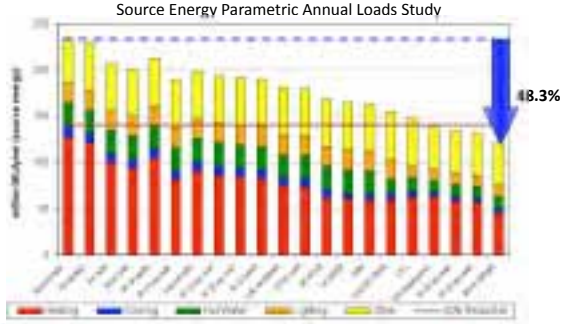
Farmhouse Retrofit

Bedford, MA

Habitat for Humanity of Greater Lowell

- Source Energy Savings

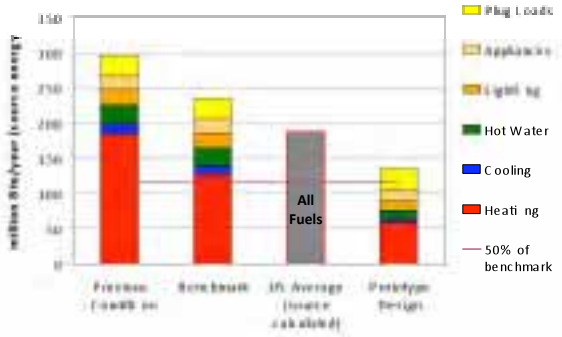
Source Energy Parametric Annual Loads Study



12 May 2009

79

Projected Energy Use



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

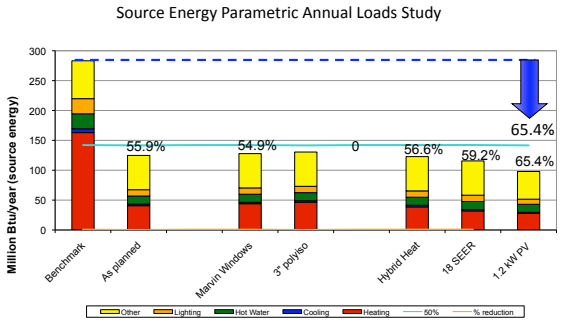
Warren Construction Group

- 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



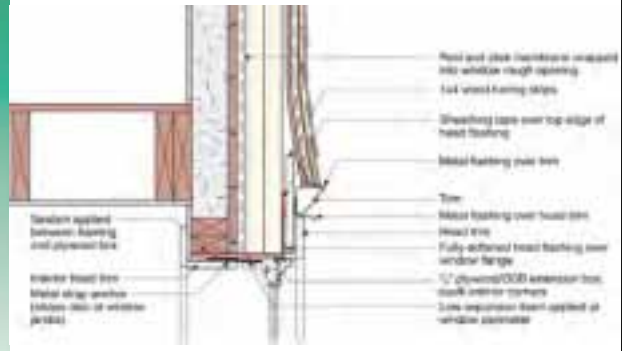
Wall Section

Freeport Retrofit

Roof – R 50

Freeport Retrofit

Wall – R 40 Windows R-5

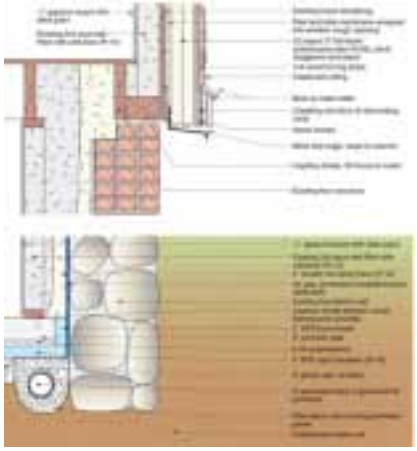


Freeport Retrofit

Foundation

Slab – R-10

Walls – R-12



Freeport Retrofit

bsc

Warren Construction Group

Freeport Retrofit

Freeport, ME

- 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

bsc

For more information go to :

www.affordablecomfort.org
see Thousand Home Challenge

www.buildingscience.com
search info and recent presentations