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Greening Affordable Housing

Building Science Corporation
www.buildingscience.com


ACI, Kansas City, MS
 April 30, 2009




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bsc Westford House Lowell HFH Lowell, MA

Westford House



Westford House Dedication Ceremony October 5th, 2008



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Project Overview

- Builder: Habitat for Humanity of Greater Lowell
- Location: Westford, MA
- Climate: Cold (5A)
- Type: Single Family, Affordable
- Stories: 1 ½
- Bedrooms: 3
- Baths: 2 Full
- Floor Area: 1340 sq. ft.
- Basement Area: 816 sq. ft.




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Project Overview


- Estimated Energy Reduction: 44.1%
- Estimated Energy Savings: \$1,259 / year
- Cost: \$200,000
- Construction Start: March 2008
- Construction Finish: October 2008
- Construction Schedule: 8 Months



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bsc How the Costs Breakdown

• Foundations installed including concrete	\$ 3,500
• Slab installed including concrete	\$ 1,000
• Lumberyard pricing of entire package including foam sheathing	\$70,000
• Framers cost to enclose building including windows and foam	\$12,500
• Electrical, Plumbing, Mechanical equipment and installation	\$30,000
• Interior finishes, cabinets, appliances, GWB and installation	\$30,000
• Septic systems and site work	\$13,000
• General labor and overhead	\$40,000
TOTAL PRE SITE GENERATED ENERGY	\$200,000
Lowell HFH donated labor	-\$40,000
Lowell HFH donated materials	-\$25,000
Total Cost to HFH	\$125,000
•3.5 kW PV system after tax credits	\$24,000
TOTAL WITH SITE GENERATE ENERGY	\$224,000
Energy Balance left: +- 400 therms of gas at \$1.50/therm	\$600 per year




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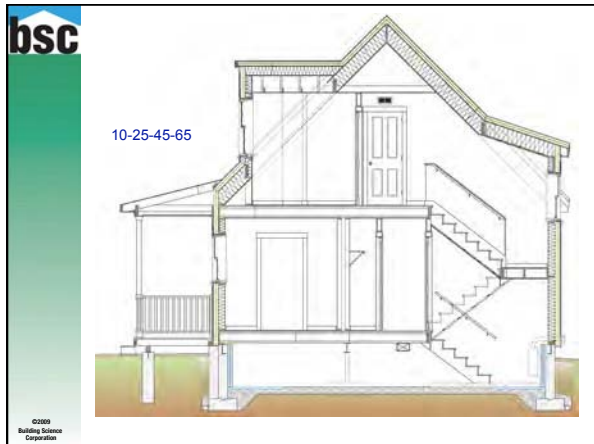
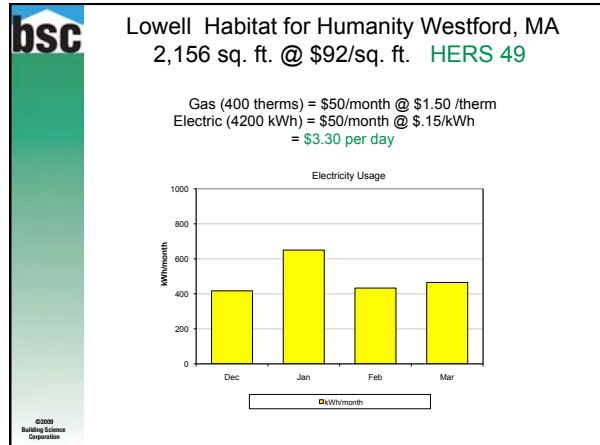
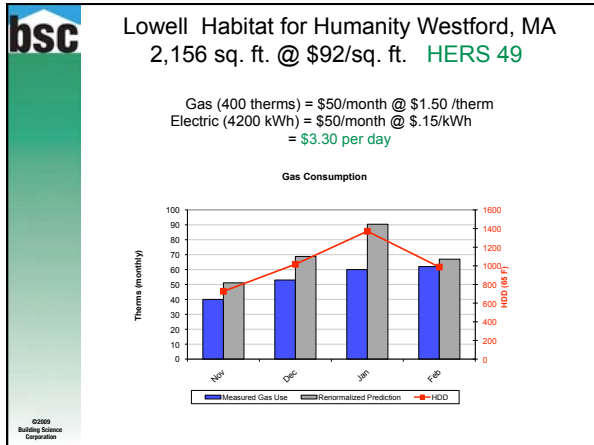
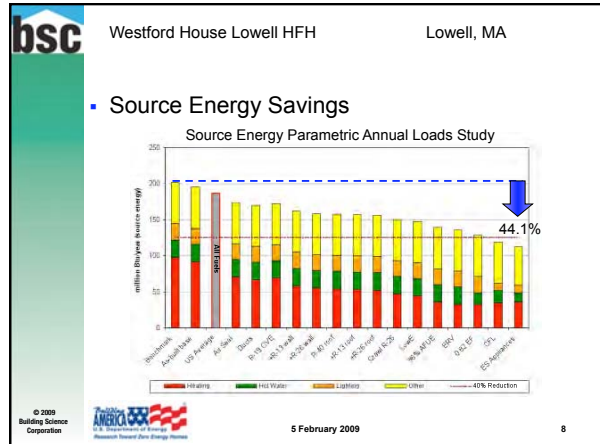
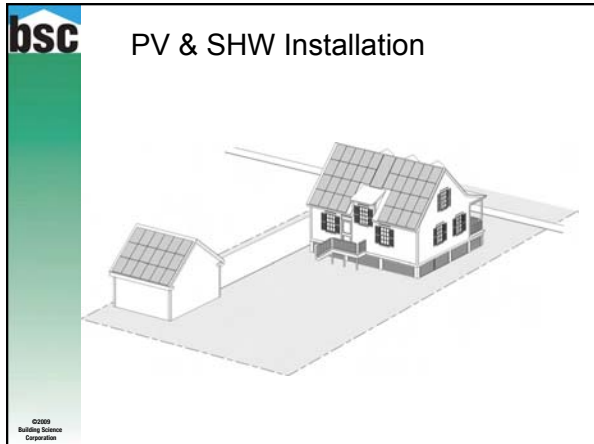
bsc Lowell Habitat for Humanity Westford, MA
 2,156 sq. ft. @ \$92/sq. ft. **HERS 49**

Gas (400 therms) = \$50/month @ \$1.50 /therm
 Electric (4200 kWh) = \$50/month @ \$.15/kWh
 = \$3.30 per day

With 3.5 kWp PV (350+- kWh/month)
 Electric = \$0





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- Enclosure Design
 - R-66 Roof Insulation (unfaced fiberglass batt insulation with (2) 2" layers foil-faced polyisocyanurate insulating sheathing on roof sheathing)
 - R-45 Walls (2x6 framing at 24" o.c. with unfaced fiberglass batt insulation and (2) 2" layers foil-faced polyisocyanurate insulating sheathing)
 - Windows (Low-E double pane argon filled, $U = 0.33$ & SHGC = 0.28)

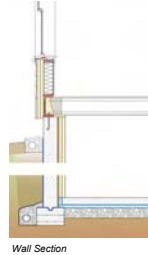


Wall Section

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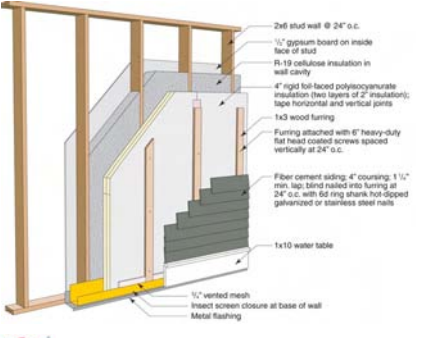
- Enclosure Design
 - R-26 Basement Walls (2) 2" layers foil-faced polyisocyanurate insulating sheathing)
 - R-13 Rim Joist Area (2" high density spray foam at first floor rim joist area)
 - R-10 Basement Slab (2" XPS below slab)



Wall Section

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- 2x6 stud wall @ 24" o.c.
- 1/2" gypsum board on inside face of stud
- R-19 cellulose insulation in wall cavity
- 4" rigid foil-faced polyisocyanurate insulation (two layers of 2" insulation); tape horizontal and vertical joints
- 1x3 wood furring
- Furring attached with 6" heavy-duty flat head coated screws spaced vertically at 24" o.c.
- Fiber cement siding, 4" coursing, 1 1/2" min. lap; blind nailed into furring at 24" o.c. with 6d ring shank hot-dipped galvanized or stainless steel nails
- 1x10 water table
- 1/2" vented mesh
- Insect screen closure at base of wall
- Metal flashing


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- Mechanical Design
 - 96% AFUE Gas Furnace
 - 0.82 EF Instantaneous Water Heater
 - Fantech Energy Recovery Ventilator (ERV)



Fantech ERV



Furnace and Return Ductwork

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- Construction Support
 - Pre-Construction Workshops
 - Demonstrations
 - Field Visits with Follow-Up Memos and Sketches



Foundation Walls



Foundation Wall Insulation



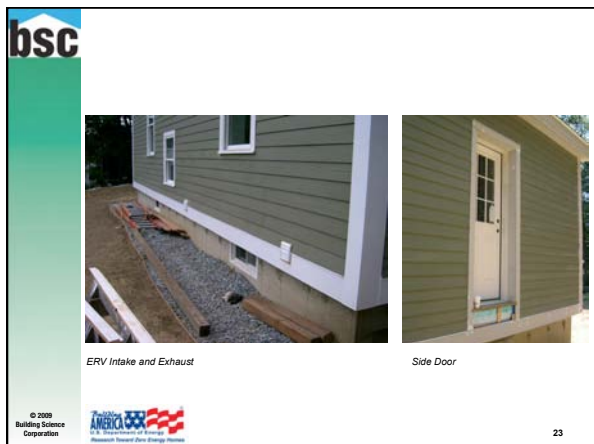
Window Flashing Demonstration

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- Systems Testing
 - Blower Door Test for Overall Air Infiltration
 - Target 1127 CFM 50 / 3.6 ACH 50
 - Results 964 CFM 50 / 3.1 ACH 50
 - Duct Blaster Test for Duct Leakage
 - No leakage to outside
 - 145 CFM total leakage at 25 Pa
 - HVAC Register Flows
 - Ventilation System Flows
 - Room Pressurization
 - HVAC System Static Pressure and Overall Flow



Blower Door Testing

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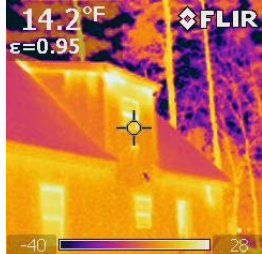
- Systems Testing Photos
 - Duct Blaster Testing
 - Duct Blaster Testing
 - Testing Register Flows
 - Installing Transfer Grille
 - Identifying Duct Leakage



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- Systems Testing Photos
 - Locating Air Leakage at Dormer
 - Locating Air Leakage at Dormer
 - Infrared Photo of Air Leakage at Bathroom Dormer

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- Prescriptive-based Code Approval
 - Meets 7th Edition Massachusetts One-and Two-Family Dwelling Code (based on 2003 ICC International Residential Code)
 - Exceeds IECC Section 404 Compliance by over 50%



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- Quality Assurance
 - Energy Models
 - Wall Mock-Up
 - Durability Checklist
 - Details in Drawing Set
 - Homeowner's Manual



Installing Siding on Wall Mock-Up

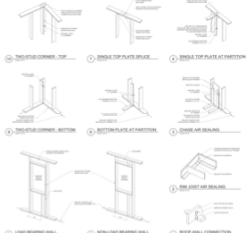
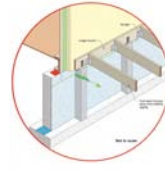
Item	Performance	Energy Model	Wall Mock-Up	Durability Checklist	Details in Drawing Set	Homeowner's Manual
A1 Air Barrier System (Below-Grade Enclosures)	✓	✓	✓	✓	✓	✓
A2 Penetration (Below-Grade Enclosures)	✓	✓	✓	✓	✓	✓
A3 Air Barrier System (Above-Ground Enclosures)	✓	✓	✓	✓	✓	✓
A4 Penetration (Above-Ground Enclosures)	✓	✓	✓	✓	✓	✓
A5 Air Sealing of Interior Cavities	✓	✓	✓	✓	✓	✓

Excerpt from Durability Checklist

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- Quality Assurance
 - Advanced Framing & Air Sealing Details from Drawing Set
 - Porch Attachment Detail

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Quality Assurance

YOUR CERTIFIED HIGH PERFORMANCE HOME

The design, construction and systems testing of your high performance home have been supported by Building Science Corporation through the U.S. Department of Energy's Building America program. The specifications to which your home has been built have allowed it to achieve certification under the LEED for Homes program as well as the Energy Star label.

Building America is a private-public partnership that conducts research to find energy-efficient solutions for new and existing housing that can be implemented throughout the residential construction industry. More information about the Building America program can be found at www.buildingamerica.gov.

LEED for Homes (Leadership in Energy and Environmental Design) is a voluntary, consensus-based rating system that promotes the design and construction of high-performance homes. More information about the LEED for Homes program can be found on the U.S. Green Building Council's website at www.usgbc.org.

Energy Star is a voluntary labeling program that identifies and promotes energy-efficient products and practices. For a new home to earn the Energy Star label, it must meet guidelines for energy efficiency set by the U.S. Environmental Protection Agency. More information about the Energy Star program can be found at www.energystar.gov.

Excerpt from Homeowner's Manual

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Quality Control

- LEED for Homes Third-Party Verification
- ENERGY STAR Third-Party Verification
- Builders Challenge Third-Party Verification
- Implementation of Durability Checklist
- Field Visits and Demonstrations

Window Installation Demonstration Verification of Complete Air Seal at Rim Joist Identification of Incomplete Air Seal at Rim Joist to be Re-Sealed

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Quality Control – BSC Information Sheets

Electric Box Penetrations

Sealing Perimeter of Drywall Assemblies

Air Barriers—Airtight Drywall Approach

Exposed board joints in airtight exterior air barrier assembly. The joints of drywall seams require a system of caulking or the field of the wall. However, several steps must be taken to ensure the airtight program is successful. It is important to note on barrier construction that caulking is not a substitute for proper installation of all penetrations through the drywall and leads to areas of the exterior which require drywall.

Drywall Assembly Penetration

An barrier assembly is the perimeter of drywall assemblies is achieved by sealing the edges of the drywall to solid framing members. This requires a continuous bead of airtight sealant.

- all exterior wall corners and top plates,
- all top plate or structural members,
- rough opening perimeters, and
- back sides of the first course stud of exterior walls.

This air seal of the perimeter wall construction is shown in green dashed lines.

Details from BSC Information Sheet on Airtight Drywall Approach – Reviewed with Drywall Installers

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Builders Challenge Certificate

U.S. Department of Energy
EnergySmart Home Scale™

Estimated annual energy savings:
Electric (kWh): \$224
Natural Gas (therms): 423
Combined floor area (sq. ft.): 1,000

Meet the Builders Challenge!

Your Score: **50**

Score Legend: 100 (Best) to 0 (Worst)

Target: 50 (Pass)

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Neutral Cost Analysis

Assumed Financing Rate: 7%
Assumed Financing Term (years): 30

Run ID	Parametric Run	Cumulative Cost	Savings	Annual Finance Cost	Simple cash flow
10	15 x ES Appliances	\$9,825	\$1,121	\$792	\$329
Add third party inspections @ \$700		\$10,525	\$1,121	\$848	\$273

Assumptions: 30 year mortgage, 7% interest rate, \$1.40/therm, \$0.18/kWh

- \$329 annual net positive cash flow (\$1121 annual savings - \$792 added mortgage cost)
- \$273 annual net positive cash flow assuming testing/inspections ~\$700 (\$1121 annual savings - \$848 added mortgage cost)

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Marketability & Market Coverage


- Low-Income Affordable Single-Family Home
- Home Built into Existing Neighborhood with Many Services within Walking Distance

Existing Home Seen Beyond Local Post Office Local Store

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- Builder Commitment**
 - Plan to build new homes in 2009 that meet Building America performance specifications:
 - 1 in Wilmington, MA
 - 2 in Dracut, MA
 - 7 in Bedford, MA



Proposed Front Elevation of New Homes

- Highlight high-performance features of their homes in marketing information such as:
 - 101 Ways We are Building Green*

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- Gaps Analysis & Lessons Learned**
 - Coordination of Ductwork and Plumbing
 - Coordination of Intake and Exhaust Locations
 - Door Installation Sequence and Details
 - First Floor Rim Joist Spray Foam Thermal Barrier
 - Attachment of Basement Wall Insulation
 - Basement Wall Insulation Thermal Barrier
 - Air-Barrier Above Second Floor Ceiling
 - Electrical Service Entrance
 - 12:12 Roof Pitch and Volunteers
 - Volunteer Labor

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- Gaps Analysis & Lessons Learned**
 - Coordination of Ductwork and Plumbing



Ductwork and Plumbing Conflict


Problem: Plumbing and ductwork competed for space at the end of the house between the rim joist and the floor joist. The 4" of foam on the basement walls constricted the space available for these services to run.

Solution: Show plumbing on plans with ductwork to identify potential conflicts.

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- Gaps Analysis & Lessons Learned**
 - Coordination of Intake and Exhaust Locations



ERV Intake and Exhaust


Problem: Equipment intakes and exhausts were relocated from original plan due to development of the site plan after the house was under construction.

Solution: Develop site plan with drawing set that identifies walkways, other proposed hardscapes and proposed utility locations.

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- Gaps Analysis & Lessons Learned**
 - Door Installation Sequence and Details



Side Door

Problem: Drawing set did not include a door installation sequence or door details to show how to install door, frame, trim and sill with 4" of foam on the walls.

Solution: Develop door installation sequence and details for drawing set.

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- Gaps Analysis & Lessons Learned**
 - First Floor Rim Joist Spray Foam Thermal Barrier



Roxul Insulation over Spray Foam


Problem: The high density spray foam installed in the rim joist area could not be left exposed without a thermal barrier.

Solution: Friction fit Roxul mineral wool insulation over spray foam and in between floor joists.

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- Gaps Analysis & Lessons Learned
 - Attachment of Basement Wall Insulation



Basement Insulation Fastener and Tape


Problem:
4" of rigid foam insulation could not be attached back to the concrete foundation wall. Furring strips were attached to the concrete and roofing washers were fastened back to furring strips holding the foam in place.

Solution:
Attach 1st layer of foam with furring and adhere 2nd layer to first layer of foam.

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- Gaps Analysis & Lessons Learned
 - Basement Wall Insulation Thermal Barrier



Gypsum Board over Foil-Faced Foam

Problem:
The foil-faced polyiso installed in the basement could not be left exposed without a thermal barrier.


Solution:
Use foil-faced polyiso that is rated as a thermal barrier or cover the foam with gypsum board.

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- Gaps Analysis & Lessons Learned
 - Air-Barrier Above Second Floor Ceiling



Second Floor Strapping and Collar Ties


Problem:
Collar ties and strapping for the second floor ceiling were installed before the gypsum serving as the air barrier was installed. It would have been difficult to install the gypsum with these members already in place.

Solution:
Move the air barrier from the interior gypsum to the roof sheathing.

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- Gaps Analysis & Lessons Learned
 - Electrical Service Entrance



Electrical Service on Front of House

Problem:
The main electrical box and wires are located in an undesired location on the front of the house.

Solution:
Ask builder for proposed utility connections to identify preferred locations.

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- Gaps Analysis & Lessons Learned
 - 12:12 Roof Pitch and Volunteers



Bathroom Dormer

Problem:
The volunteers had a difficult time installing the siding and trim on the dormers while standing on the main roof which has a 12:12 pitch.


Solution:
Design house to have a lower sloped roof or to not have any dormers.

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- Gaps Analysis & Lessons Learned
 - Volunteer Labor



Air Leakage in Sheet Metal Duct


Problem:
The volunteers had a difficult time with air sealing, particularly around the windows and along the ductwork.

Solution:
Have brief meetings at the start of each day to demonstrate each task or assign one volunteer per task to oversee their group.

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- Conclusion
 - BSC looks forward to working with Habitat in 2009 to provide healthy, durable, energy-efficient and affordable homes to families in need throughout the Greater Lowell area



Community Gathered before Westford House Dedication Ceremony


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SINGLE FAMILY REHAB- BEDFORD, MA

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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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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 (*Outsulation!*)
 - 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

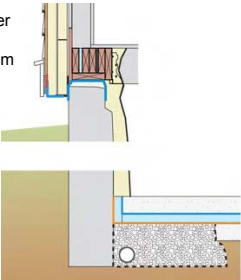

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Basement Details

- 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

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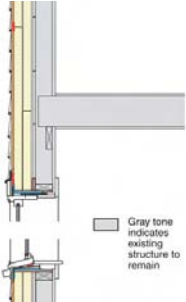
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Wall Details

- 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


Gray tone indicates existing structure to remain

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Window installation



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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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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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