Building Smaller, Building Better:
Getting to Net Zero Ready by Design

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Building Science Corporation
www.buildingscience.com

BETTER BUILDINGS BY DESIGN CONFERENCE
Burlington, VT February 12, 2009

Westford House — Westford, MA

Habitat for Humanity of Greater Lowell

Westford House

Westford House Dedication Ceremony October 5th, 2008

Westford House — Westford, MA

Habitat for Humanity of Greater Lowell

- 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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Habitat for Humanity of Greater Lowell

- 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

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
• Framer's 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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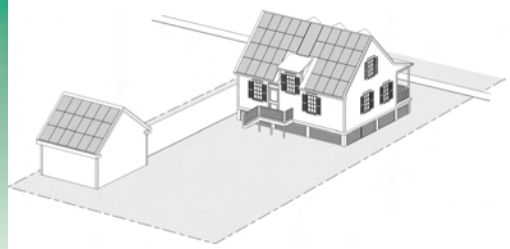
Lowell Habitat for Humanity Westford, MA
2,156 sq. ft. @ $92/sq. ft. HERS 49

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

PV & SHW Installation



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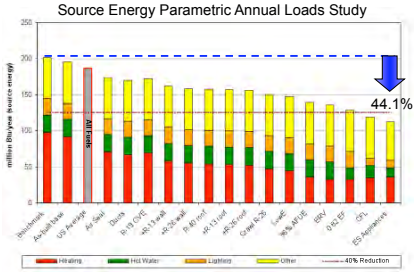
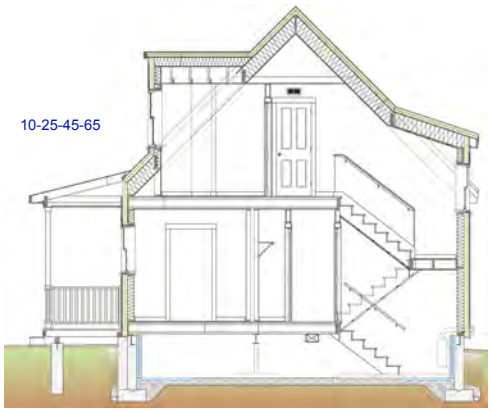
- Source Energy Savings

Source Energy Parametric Annual Loads Study





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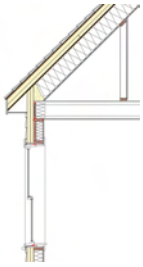
Habitat for Humanity of Greater Lowell

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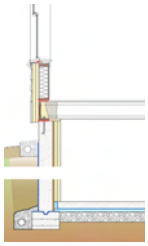
- Enclosure Design
  - R-26 Basement Walls (2) 2" layers foil-faced polyisocyanurate insulating sheathing)
  - R-13 Rim Joist Area (2" high density spray foam at first floor rim joist area)
  - R-10 Basement Slab (2" XPS below slab)



Wall Section

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- 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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Habitat for Humanity of Greater Lowell

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


Foundation Wall Insulation


Foundation Walls


Window Flashing Demonstration

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- Construction Support Photos


Roof Framing


Roof Insulation


Fastening Furring Strip


BSC Team On-Site Meeting

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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


Installing Transfer Grille


Identifying Duct Leakage


Duct Blaster Testing


Testing Register Flows

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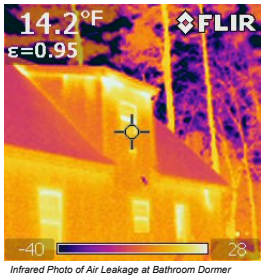
Habitat for Humanity of Greater Lowell

- 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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Habitat for Humanity of Greater Lowell

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

Installing Siding on Wall Mock-Up

Excerpt from Durability Checklist

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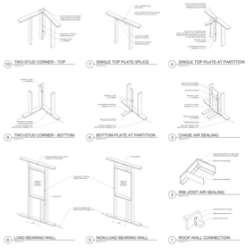
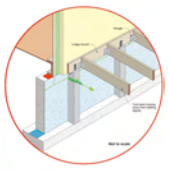
Habitat for Humanity of Greater Lowell

- Quality Assurance



Advanced Framing & Air Sealing Details from Drawing Set



Porch Attachment Detail

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- Quality Assurance

Excerpt from Homeowner's Manual

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Habitat for Humanity of Greater Lowell

- 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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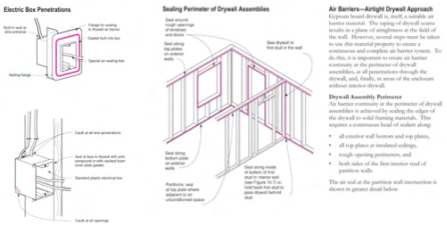
Habitat for Humanity of Greater Lowell

- Quality Control – BSC Information Sheets



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

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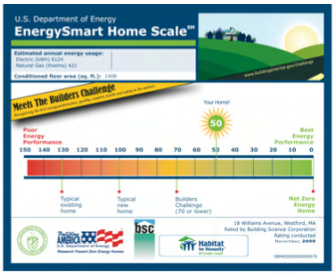
- Builders Challenge Certificate



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Habitat for Humanity of Greater Lowell

- Neutral Cost Analysis

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

Run ID	Parametric Run	Cumulative Cost	Annual Finance Savings	Annual Finance Cost	Simple cash flow
16	15 + 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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Habitat for Humanity of Greater Lowell

- 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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Habitat for Humanity of Greater Lowell

- 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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Habitat for Humanity of Greater Lowell

- 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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Habitat for Humanity of Greater Lowell

- 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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Habitat for Humanity of Greater Lowell

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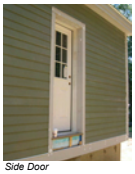
- Gaps Analysis & Lessons Learned
  - Door Installation Sequence and Details



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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Habitat for Humanity of Greater Lowell

- 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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Habitat for Humanity of Greater Lowell

- 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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Habitat for Humanity of Greater Lowell

- 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