

Massachusetts Deep Energy Retrofits
Persistent Challenges and Performance

Building Energy 2012
Boston, MA



Deep Energy Retrofit

- Persistent Challenges
- (energy) Performance

Boston, MA
March 6th, 2012

2



Heat Flow Is From Warm To Cold
Moisture Flow Is From Warm To Cold
Moisture Flow Is From More To Less
Air Flow Is From A Higher Pressure to a
Lower Pressure
Gravity Acts Down

Building Science Corporation

Joseph Lstiburek 3

Deep Energy Retrofit

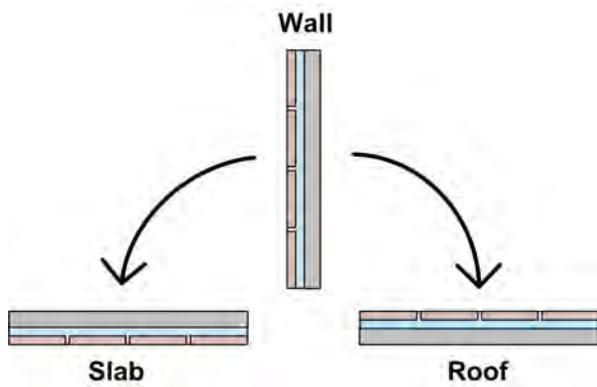
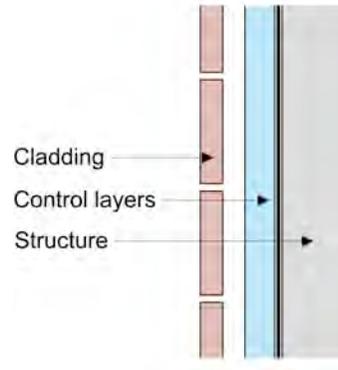
Questions?

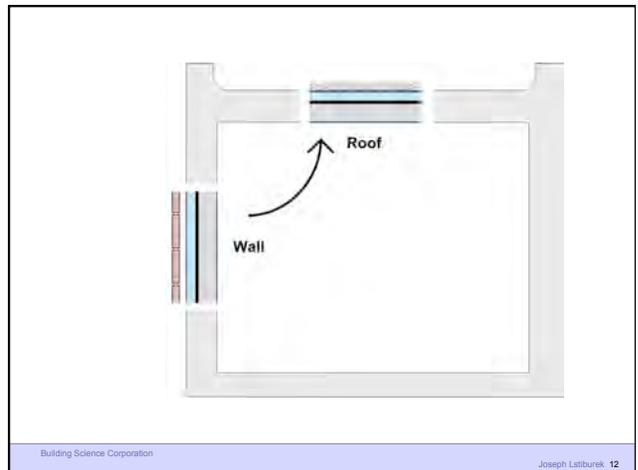
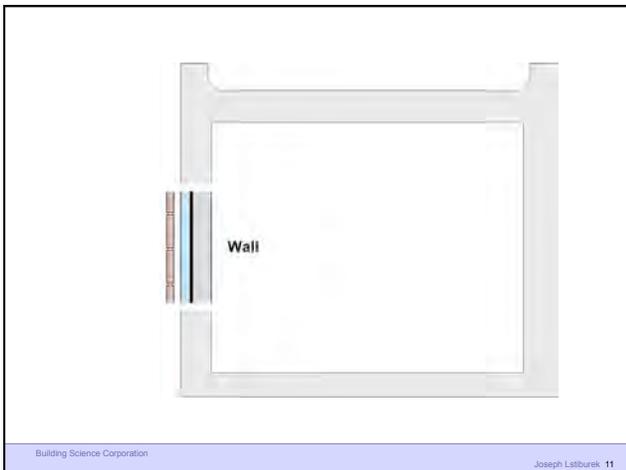
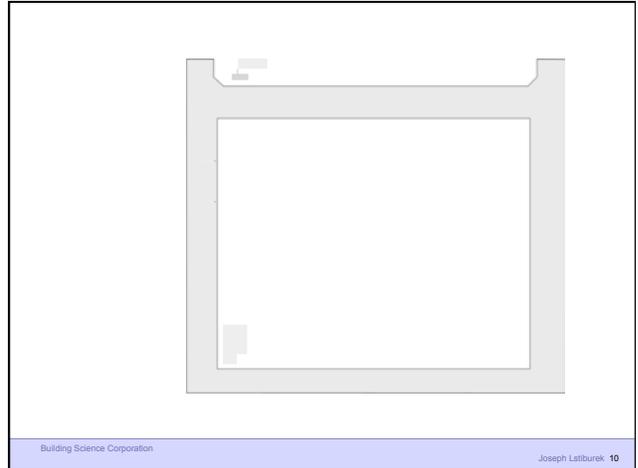
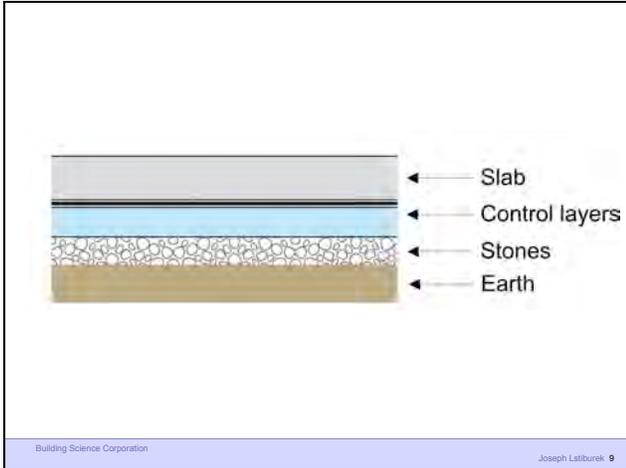
Boston, MA
March 6th, 2012

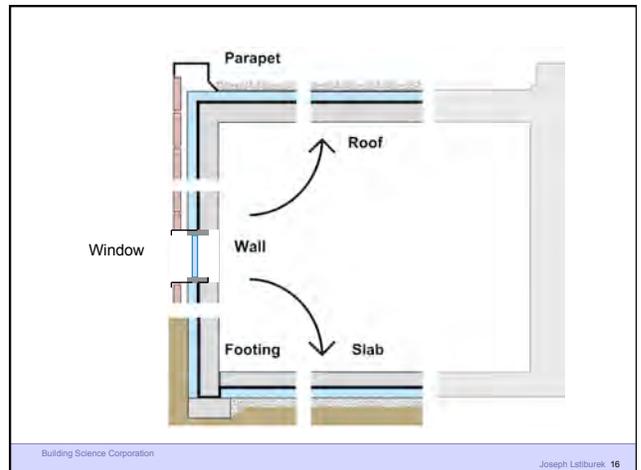
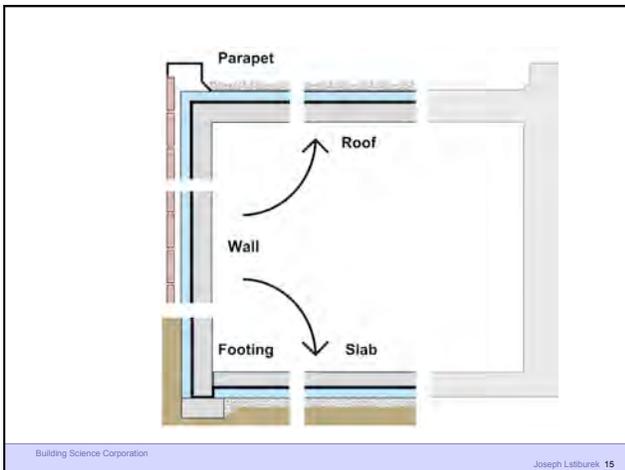
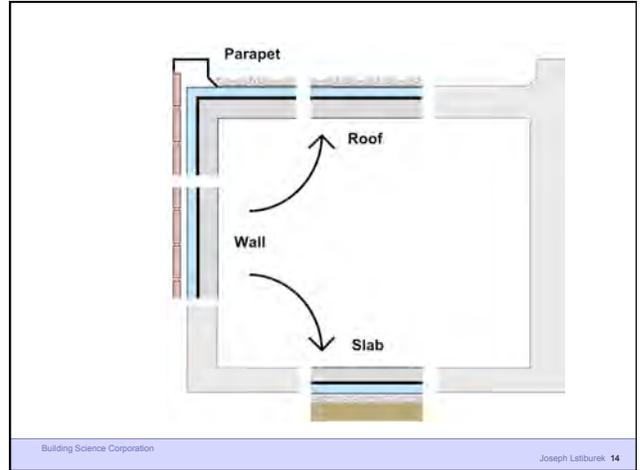
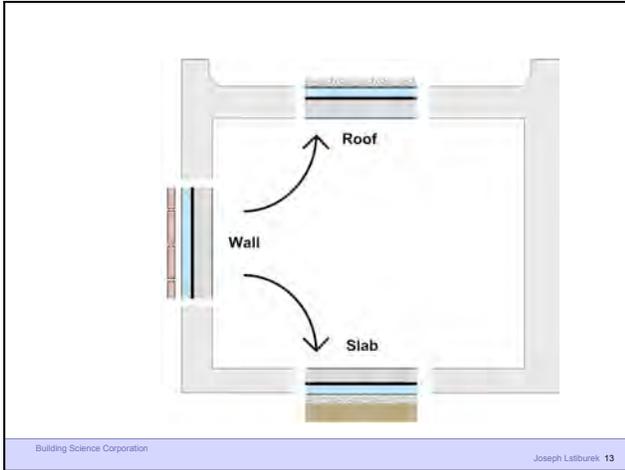
4



Water Control Layer
Air Control Layer
Vapor Control Layer
Thermal Control Layer







Deep Energy Retrofits – Persistent Challenges

Perfect wall meets existing wall:

- Cladding/finishes already in place
- Structure interrupts control layers
- Control layers not present
 - What are the control layers?
 - Where are the control layers?
 - Where do the control layers go?

Boston, MA
March 6th, 2012

17



Water Control Layer
Air Control Layer
Vapor Control Layer
Thermal Control Layer

Building Science Corporation

Joseph Lstiburek 18

Deep Energy Retrofits – Persistent Challenges

- Where is the water control?
- Window flashing
- Can't we just...?
- Where should the insulation be in wall and roof?
- Where should the thermal enclosure be with respect to the basement?
- What if we can only do part of it now?
- Communicating intent to get performance built
- It's the whole (hole) enclosure
- Continuity of control at porch, deck, roof, structure
- Helpful and nifty stuff

Boston, MA
March 6th, 2012

19



Deep Energy Retrofits – Persistent Challenges

- Where is the water control?
- Window flashing
- Can't we just...?
- Where should the insulation be in wall and roof?
- Where should the thermal enclosure be with respect to the basement?
- What if we can only do part of it now?
- Communicating intent to get performance built
- It's the whole (hole) enclosure
- Continuity of control at porch, deck, roof, structure
- Helpful and nifty stuff

Boston, MA
March 6th, 2012

20



Deep Energy Retrofits – Persistent Challenges

- Where is the water control?

Boston, MA
March 6th, 2012

21



Deep Energy Retrofit Measures Verification

You've got to see it to...

- Flashing misses



Boston, MA
March 6th, 2012

22



Deep Energy Retrofits – Persistent Challenges

Exterior insulation drainage plane is not where it used to be



Boston, MA
March 6th, 2012

23



Deep Energy Retrofits – Persistent Challenges

Exterior insulation drainage planes sequencing:



Boston, MA
March 6th, 2012

24



Deep Energy Retrofit Measures Verification

- Roof-Wall flashing sequence



Boston, MA
March 6th, 2012

25



Deep Energy Retrofit Measures Verification

You've got to see it to...



Boston, MA
March 6th, 2012

26



Deep Energy Retrofits – Persistent Challenges

- Where is the water control?

Boston, MA
March 6th, 2012

27



Deep Energy Retrofits – Persistent Challenges

- Window/door flashing

Boston, MA
March 6th, 2012

28



Deep Energy Retrofits – Persistent Challenges

- Window flashing



Boston, MA
March 6th, 2012

29



Deep Energy Retrofits – Persistent Challenges

Flashing challenges



Boston, MA
March 6th, 2012

30



Deep Energy Retrofits – Persistent Challenges

Window flashing challenges



Boston, MA
March 6th, 2012

31



Deep Energy Retrofits – Persistent Challenges

Window flashing challenges



Boston, MA
March 6th, 2012

32



Deep Energy Retrofits – Persistent Challenges

Flashing challenges



Boston, MA
March 6th, 2012

33



Deep Energy Retrofits – Persistent Challenges

Flashing challenges



Boston, MA
March 6th, 2012

34



Deep Energy Retrofits – Persistent Challenges

Mock-up makes perfect

- Window flashing mock up



Boston, MA
March 6th, 2012

35



Deep Energy Retrofits – Persistent Challenges

Mock-up makes perfect

- Window flashing mock up

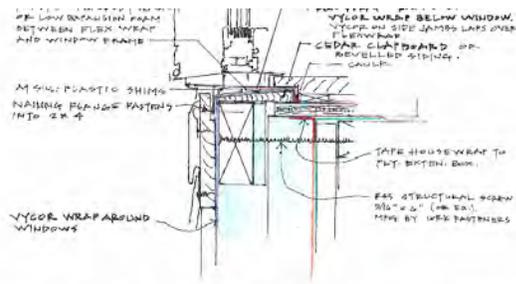


Boston, MA
March 6th, 2012

36



Deep Energy Retrofits – Persistent Challenges



HH-32 CARTER ST. Rev. 6-13-11 TRANSFORMATION 4-B-11

Boston, MA
March 6th, 2012

37



Deep Energy Retrofits – Persistent Challenges

Window aligned with drainage plane



Boston, MA
March 6th, 2012

38



Deep Energy Retrofits – Persistent Challenges

Window installed with minimal disruption to interior



Boston, MA
March 6th, 2012

39



Deep Energy Retrofits – Persistent Challenges

Window flashing saved



Boston, MA
March 6th, 2012

40



Deep Energy Retrofits – Persistent Challenges

- Window/door flashing

Boston, MA
March 6th, 2012

41



Deep Energy Retrofits – Persistent Challenges

- Can't we just...

Boston, MA
March 6th, 2012

42



Deep Energy Retrofit Measures Verification

Are you sure you want to do that?



Boston, MA
March 6th, 2012

43



Deep Energy Retrofit Measures Verification

Are you sure you want to do that?



Boston, MA
March 6th, 2012

44



Deep Energy Retrofit Measures Verification

Are you sure you want to do that?



Boston, MA
March 6th, 2012

45



Deep Energy Retrofit Measures Verification

- Inspection of critical details revealed problems in existing conditions



Boston, MA
March 6th, 2012

46



Deep Energy Retrofits – Persistent Challenges

- Can't we just...

Boston, MA
March 6th, 2012

47



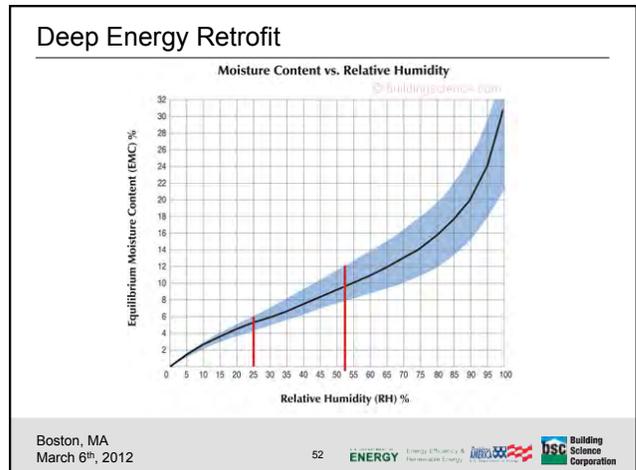
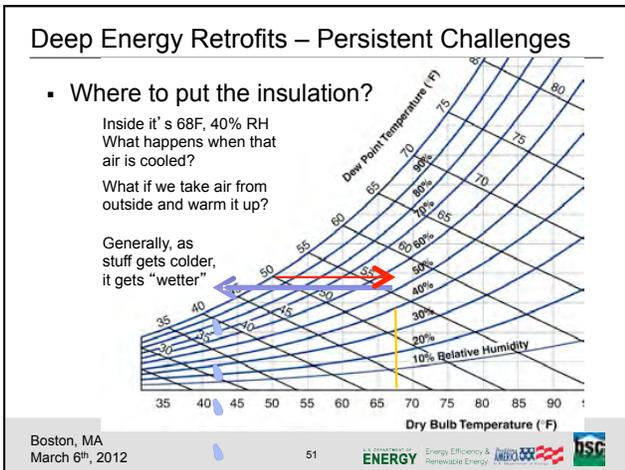
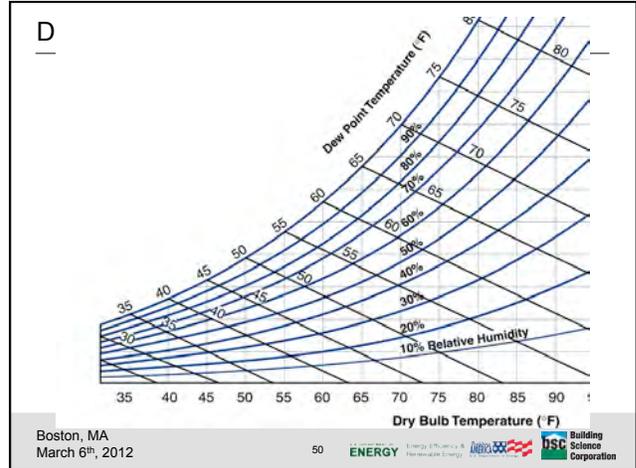
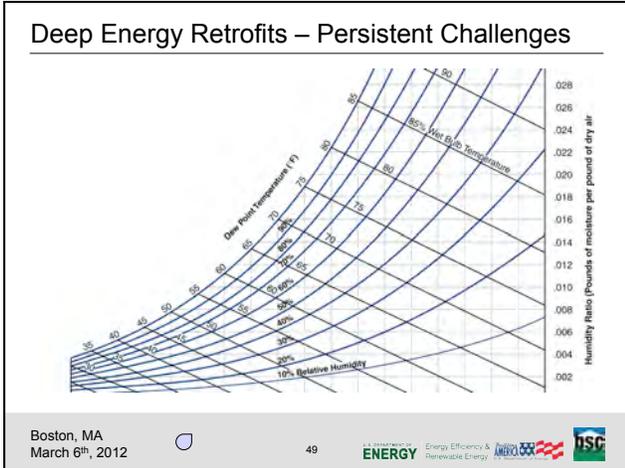
Deep Energy Retrofits – Persistent Challenges

- Where should the insulation be?
 - Cavity insulation, or
 - Continuous exterior insulation, or
 - Continuous interior insulation

Boston, MA
March 6th, 2012

48





Deep Energy Retrofits – Persistent Challenges



Existing replacement windows installed without flashing

Boston, MA
March 6th, 2012

53



Deep Energy Retrofits – Persistent Challenges

- Inspection of critical details revealed problems in existing conditions



Boston, MA
March 6th, 2012

54



Deep Energy Retrofits – Persistent Challenges

- Inspection of critical details revealed problems in existing conditions



Boston, MA
March 6th, 2012

55



Deep Energy Retrofits – Persistent Challenges

- Inspection of critical details revealed problems in existing conditions



Boston, MA
March 6th, 2012

56



Deep Energy Retrofits – Persistent Challenges

- Drainage remediation



Boston, MA
March 6th, 2012

57



Deep Energy Retrofits – Persistent Challenges

- Roof overhang and roof insulation



Boston, MA
March 6th, 2012

58



Deep Energy Retrofits – Persistent Challenges

- Roof overhang and roof insulation



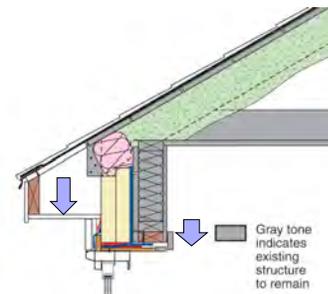
Boston, MA
March 6th, 2012

59



Deep Energy Retrofits – Persistent Challenges

- Roof overhang and roof insulation



Boston, MA
March 6th, 2012

60



Deep Energy Retrofits – Persistent Challenges

- Where should the insulation be?

Boston, MA
March 6th, 2012

61



Deep Energy Retrofits – Persistent Challenges

- Where should the thermal enclosure be with respect to the basement?

Boston, MA
March 6th, 2012

62



Deep Energy Retrofits – Persistent Challenges

- What is a basement?
 - Damp
 - Stinky
 - Cold
 - Funky
 - Wet
 - Made of rocks
 - Expensive to build
 - Useful space
 - Potential amenity
 - Space for mechanical systems
 - Made of rocks



Boston, MA
March 6th, 2012

63



Deep Energy Retrofits – Persistent Challenges

- Should a basement be in or out?
- Do we have a choice?

Boston, MA
March 6th, 2012

64



Deep Energy Retrofits – Persistent Challenges



- 4.6 ACH50;
2129 CFM 50 total;
1100 CFM 50 through
floor over basement
- 7.3 ACH50;
3590 CFM 50 total;
1740 CFM 50 through
floor over basement

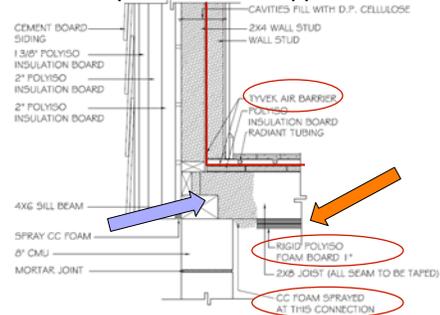
Boston, MA
March 6th, 2012

65



Deep Energy Retrofits – Persistent Challenges

▪ Basement Separation: Bold Approach



Boston, MA
March 6th, 2012

66



Deep Energy Retrofits – Persistent Challenges

- Extraordinary approach to basement separation:
 - ~400 cfm50 across basement ceiling (of ~1,900 total)
 - More than leakage between apartments (~200 cfm50 inter-unit leakage)
 - ~20% of total enclosure leakage area for combined living area
 - ~30% of total enclosure leakage for lower apartment
 - ~15% of total enclosure leakage for upper apartment

Boston, MA
March 6th, 2012

67



Deep Energy Retrofits – Persistent Challenges

- Where should the thermal enclosure be with respect to the basement?

Boston, MA
March 6th, 2012

68



Deep Energy Retrofits – Persistent Challenges

- What if we can only do part of it now?

Boston, MA
March 6th, 2012

69



DER Project Plans – Staged DER

- Staged DER = Long range planning
 - We do what we can now
 - Anticipate where we want to go in the future

Boston, MA
March 6th, 2012

70



Staged DER



Boston, MA
March 6th, 2012

71



DER Project Plans – Staged DER

- Staged DER = Long range planning
 - High performance retrofit measures
 - Connect to existing components
 - Transfer control functions to existing components
 - Anticipate connection to future components
 - Transfer control functions to new components
 - Make the next guys job easier

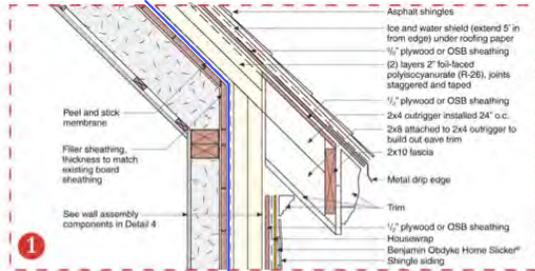
Boston, MA
March 6th, 2012

72



Staged DER

- Roof retrofit

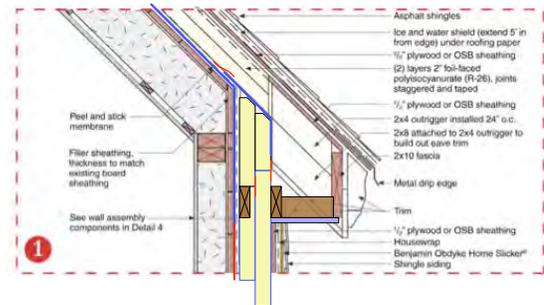


Boston, MA
March 6th, 2012

73



Staged DER – Roof First



Boston, MA
March 6th, 2012

74



Staged DER



Boston, MA
March 6th, 2012

75



Staged DER



Boston, MA
March 6th, 2012

76



Staged DER



Boston, MA
March 6th, 2012

77



Staged DER



Boston, MA
March 6th, 2012

78



Staged DER



Boston, MA
March 6th, 2012

79



Staged DER



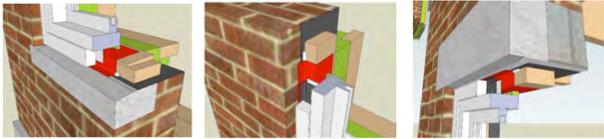
Boston, MA
March 6th, 2012

80



Staged DER

- Window Retrofit



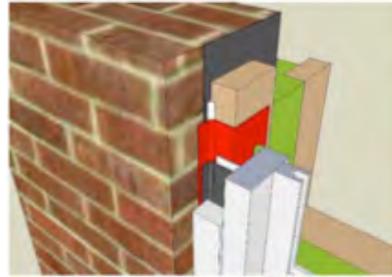
Boston, MA
March 6th, 2012

81



Staged DER

- Window Retrofit



Boston, MA
March 6th, 2012

82



Staged DER



Boston, MA
March 6th, 2012

83



Deep Energy Retrofits – Persistent Challenges

- What if we can only do part of it now?

Boston, MA
March 6th, 2012

84



Deep Energy Retrofits – Persistent Challenges

- Communicating intent to get performance built

Boston, MA
March 6th, 2012

85



DER Measures Specification – Be Specific!

Control Functions Guide Specification

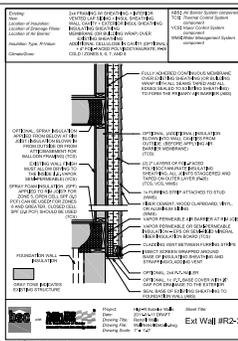
- Enclosure:
 - Water control
 - Air flow control
 - Vapor Control
 - Thermal Control
- Mechanical:
 - Space heating
 - Space cooling
 - Ventilation
 - Air mixing
 - Water heating

Boston, MA
March 6th, 2012

86



DER Measures Specification

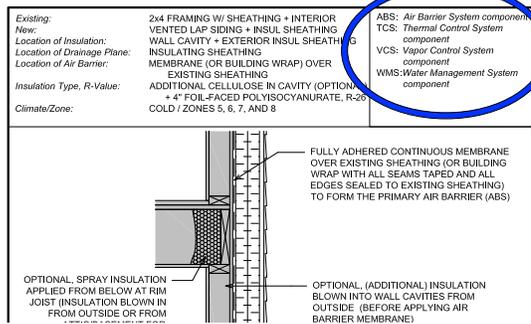


Boston, MA
March 6th, 2012

87



DER Measures Specification



Boston, MA
March 6th, 2012

88



DER Measures Specification

Boston, MA
March 6th, 2012

89 ENERGY Energy Efficiency & Renewable Energy AMEC PARSONS Building Science Corporation

DER Measures Specification – Being Specific

- Communicate the *functional intent*
 - Very difficult to anticipate every condition
 - Empowers person in the field:
 - Water control → down and out
 - Air flow control → make connections air tight
 - Thermal control → avoid putting bridges through it
 - Vapor control → where is moisture sensitive material?
which direction is the vapor drive?
do we need to allow diffusion or control it?

Boston, MA
March 6th, 2012

90 ENERGY Energy Efficiency & Renewable Energy AMEC PARSONS Building Science Corporation

DER Measures Specification

Boston, MA
March 6th, 2012

91 ENERGY Energy Efficiency & Renewable Energy AMEC PARSONS Building Science Corporation

DER Measures Specification

Boston, MA
March 6th, 2012

92 ENERGY Energy Efficiency & Renewable Energy AMEC PARSONS Building Science Corporation

DER Measures Specification

NOTE: AIR BARRIER AT ADDITION TO BE TAPED
SHEATHING AND EXTERIOR FOAM INSULATION AT
FOUNDATION WALL

BLOWER DOOR PRESSURE TEST TO BE CONDUCTED AT COMPLETION OF AIR BARRIER BEFORE INSTALLATION OF INTERIOR WALL FINISHES.
DIAGNOSTIC FOG TESTING WILL BE CONDUCTED TO FIND FLAWS IN AIR BARRIER SYSTEMS

PRESSURE TESTING TARGET: 0.1CFM50 / SQUARE FOOT OF SHELL

TARGET CFM50 OF FINAL BLOWER DOOR:
580CFM50



Boston, MA
March 6th, 2012

93



DER Project Plans

- It's important to have a plan!
(It's important to plan)

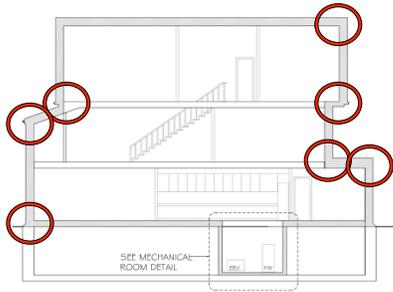
Boston, MA
March 6th, 2012

94



Deep Energy Retrofit Measures Verification

Plan Review - Enclosure



Boston, MA
March 6th, 2012

95



Deep Energy Retrofit Measures Verification



Boston, MA
March 6th, 2012

96



Deep Energy Retrofit Measures Verification

Boston, MA
March 6th, 2012

97

ENERGY Energy Efficiency & Renewable Energy

AMERICA'S ENERGY EFFICIENCY REVOLUTION

DSC Building Science Corporation

Deep Energy Retrofits – Persistent Challenges

- Communicating intent to get performance built

Boston, MA
March 6th, 2012

98

ENERGY Energy Efficiency & Renewable Energy

AMERICA'S ENERGY EFFICIENCY REVOLUTION

DSC Building Science Corporation

Deep Energy Retrofits – Persistent Challenges

- It's the whole (hole) enclosure

Boston, MA
March 6th, 2012

99

ENERGY Energy Efficiency & Renewable Energy

AMERICA'S ENERGY EFFICIENCY REVOLUTION

DSC Building Science Corporation

Deep Energy Retrofit Measures Verification

You've got to see it to...

- Significant components not on plans

Boston, MA
March 6th, 2012

100

ENERGY Energy Efficiency & Renewable Energy

AMERICA'S ENERGY EFFICIENCY REVOLUTION

DSC Building Science Corporation

Deep Energy Retrofit Measures Verification

You've got to see it to...

- Significant components not on plans



Boston, MA
March 6th, 2012

101



Deep Energy Retrofits – Persistent Challenges

- It's the whole (hole) enclosure

Boston, MA
March 6th, 2012

102



Deep Energy Retrofits – Persistent Challenges

- Continuity of control at porch, deck, roof, structure

Boston, MA
March 6th, 2012

103



Deep Energy Retrofit Measures Verification

You've got to see it to...

- Control function lapses



Boston, MA
March 6th, 2012

104



Deep Energy Retrofit Measures Verification

You've got to see it to...

- Continuity of control function



Boston, MA
March 6th, 2012

105 ENERGY Energy Efficiency & Renewable Energy AMERICA'S ENERGY EFFICIENCY REVOLUTION DSC Building Science Corporation

Deep Energy Retrofit Measures Verification

You've got to see it to...



Boston, MA
March 6th, 2012

106 ENERGY Energy Efficiency & Renewable Energy AMERICA'S ENERGY EFFICIENCY REVOLUTION DSC Building Science Corporation

Deep Energy Retrofit Measures Verification

You've got to see it to...

- Control function lapses



Boston, MA
March 6th, 2012

107 ENERGY Energy Efficiency & Renewable Energy AMERICA'S ENERGY EFFICIENCY REVOLUTION DSC Building Science Corporation

Deep Energy Retrofit Measures Verification

You've got to see it to...

- Control function recovery



Boston, MA
March 6th, 2012

108 ENERGY Energy Efficiency & Renewable Energy AMERICA'S ENERGY EFFICIENCY REVOLUTION DSC Building Science Corporation

Deep Energy Retrofit Measures Verification

You've got to see it to...

- Continuity of control functions



Boston, MA
March 6th, 2012

109



Deep Energy Retrofit Measures Verification

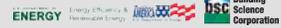
You've got to see it to...

- Continuity of control functions



Boston, MA
March 6th, 2012

110



Deep Energy Retrofits – Persistent Challenges



Boston, MA
March 6th, 2012

111



Deep Energy Retrofit Measures Verification

You've got to see it to...

- Deck ledger over everything



Boston, MA
March 6th, 2012

112



Deep Energy Retrofit Measures Verification

You've got to see it to...

- Built up siding detail over foam



Boston, MA
March 6th, 2012

113



Deep Energy Retrofit Measures Verification

You've got to see it to...

- Built up siding detail over foam



Boston, MA
March 6th, 2012

114



Deep Energy Retrofit Measures Verification



Boston, MA
March 6th, 2012

115



Deep Energy Retrofit Measures Verification

You've got to see it to...



Boston, MA
March 6th, 2012

116



Deep Energy Retrofits – Persistent Challenges

- Continuity of control at porch, deck, roof, structure

Boston, MA
March 6th, 2012

117



Deep Energy Retrofits – Persistent Challenges

- Helpful and nifty stuff

Boston, MA
March 6th, 2012

118



Deep Energy Retrofits – Persistent Challenges

- Slab insulation sequencing



Boston, MA
March 6th, 2012

119



Deep Energy Retrofits – Persistent Challenges

- Slab insulation sequencing



Boston, MA
March 6th, 2012

120



Deep Energy Retrofits – Persistent Challenges

- Window installation
 - 2x bucks let in to exterior foam allow for “standard practice” installation



Flanges attached to 2X frame surround



Existing interior trim retained

Boston, MA
March 6th, 2012

121



Deep Energy Retrofits – Persistent Challenges

- Design Challenge – A River Runs Through It
 - Condition of basement very important
 - Pre-retrofit, standing (flowing) water in basement



Boston, MA
March 6th, 2012

122



Deep Energy Retrofits – Persistent Challenges

- Design Challenge – A River Runs Through It
 - Condition of basement very important
 - Pre-retrofit, standing (flowing) water in basement

Retrofit Plan:

- Trenches, drain pipe to daylight, gravel
- 6 mil poly
- More gravel
- SPF on walls

DER project guidance:

- Insulation
- Concrete slab
- Poly in contact with concrete
- 12” high XPS at slab perimeter

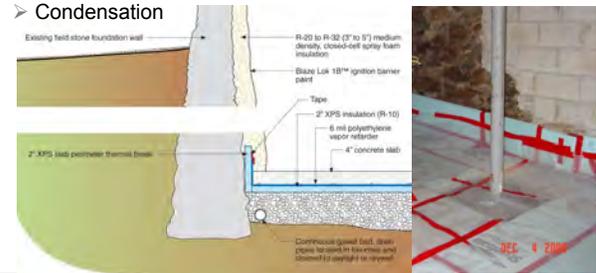
Boston, MA
March 6th, 2012

123



Design Challenge: A River Runs Through It

- Bulk water
- Capillary transfer
- Condensation
- Convective transfer
- Difusion



Boston, MA
March 6th, 2012

124



Deep Energy Retrofits – Persistent Challenges

- “Chain saw” approach



Boston, MA
March 6th, 2012

125



Deep Energy Retrofits – Persistent Challenges

- “Chain saw” approach



Boston, MA
March 6th, 2012

126



Deep Energy Retrofits – Persistent Challenges

- Vapor diffusion drying for framing sill



Boston, MA
March 6th, 2012

127



Deep Energy Retrofits – Persistent Challenges

- Vapor diffusion drying for framing sill



Boston, MA
March 6th, 2012

128



Deep Energy Retrofits – Persistent Challenges

- Cladding attachment over semi-rigid mineral wool insulation
 - It Works!**



Boston, MA
March 6th, 2012

129



Deep Energy Retrofits – Persistent Challenges

- Enclosure – Roof/Attic
 - Water Management** – New asphalt shingle roof
 - Air Control** – Continuous 1” spray foam at attic floor and connected to wall housewrap
 - Vapor Control** – 1” closed-cell spray foam and vented roof
 - Thermal Control** – 18” blown in cellulose over 1” closed-cell spray foam



Critical air seal at attic floor



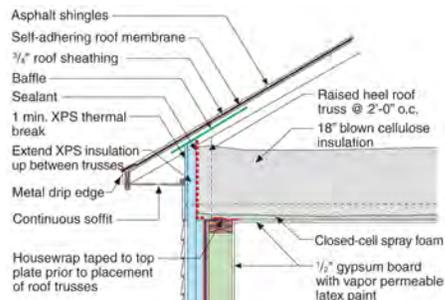
House wrap sealed to wall top plate

Boston, MA
March 6th, 2012

130



Deep Energy Retrofits – Persistent Challenges



Boston, MA
March 6th, 2012

131



Deep Energy Retrofits – Persistent Challenges

- Enclosure – Basement Floor
 - Water Control:** 4-6" gravel layer
 - Air Control:** New concrete slab
 - Vapor Control:** Polyethylene under the slab w polyethylene and concrete*
 - Thermal Control:** 2" XPS rigid insulation

*BSC does not recommend using sand under the new slab



Vapor barrier over XPS with sand before slab is poured



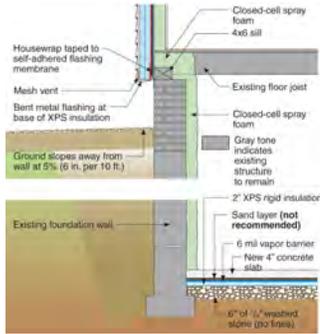
New concrete slab

Boston, MA
March 6th, 2012

132



Deep Energy Retrofits – Persistent Challenges



Boston, MA
March 6th, 2012

133



Deep Energy Retrofits – Persistent Challenges

- Helpful and nifty stuff

Boston, MA
March 6th, 2012

134

