VERMONT ENERGY INVESTMENT CORPORATION

NYSERDA Deep Energy Retrofit Contractor Training

December, 2010

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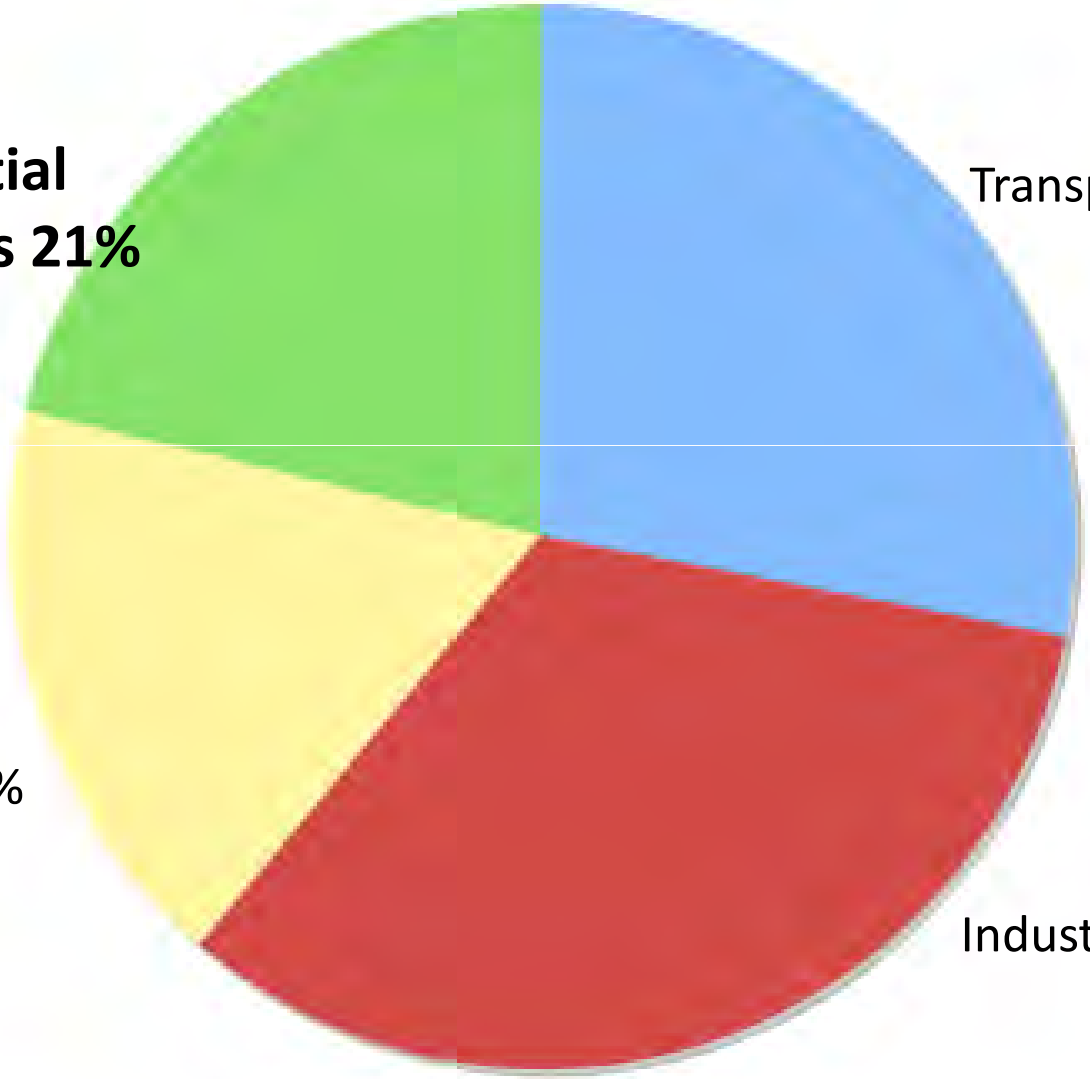
This workshop will address:

- What is a Deep Energy Retrofit (DER)?
- Building science underlying DERs
- Where the heat goes in houses
- Utica Case studies of DERs and approaches used
-Ventilation and heating for DERs
- Issues brought by participants

US Primary Energy Use by Sector



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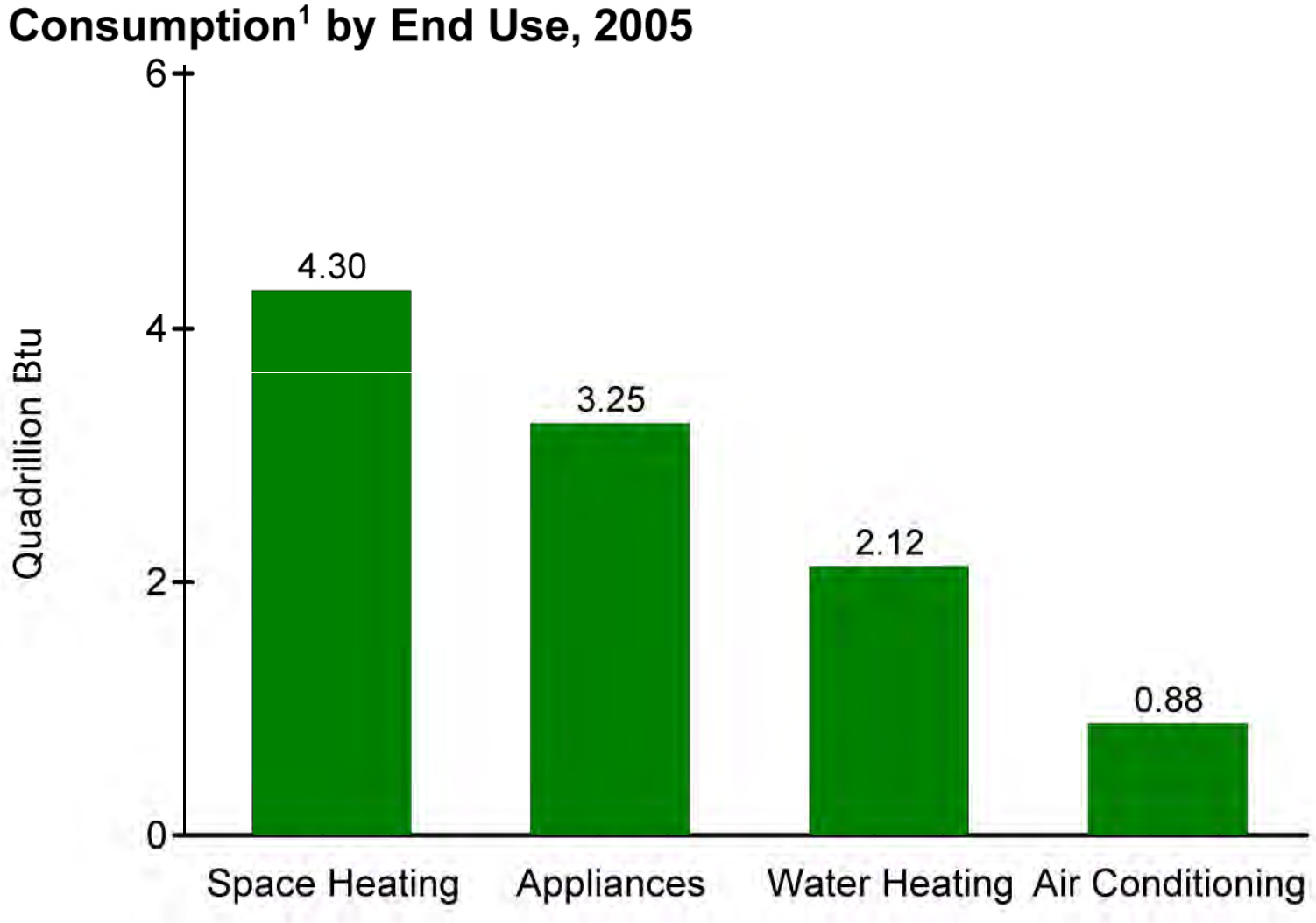
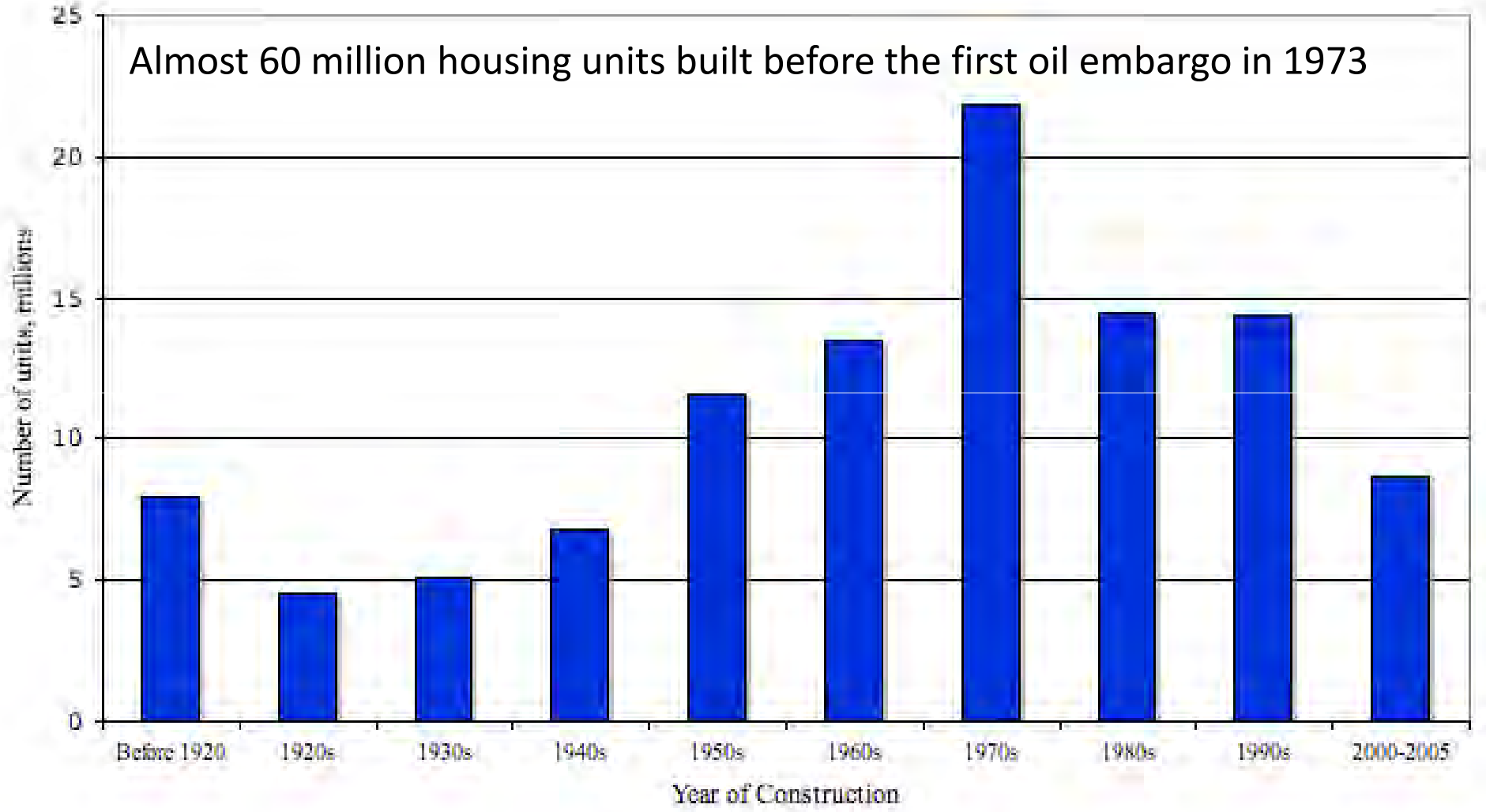
Residential Building Energy Consumption in US



U.S. DOE: http://www.eia.doe.gov/emeu/aer/pdf/pages/sec2_18.pdf

Age of Existing US Housing Stock



Source: American Housing Survey 2005

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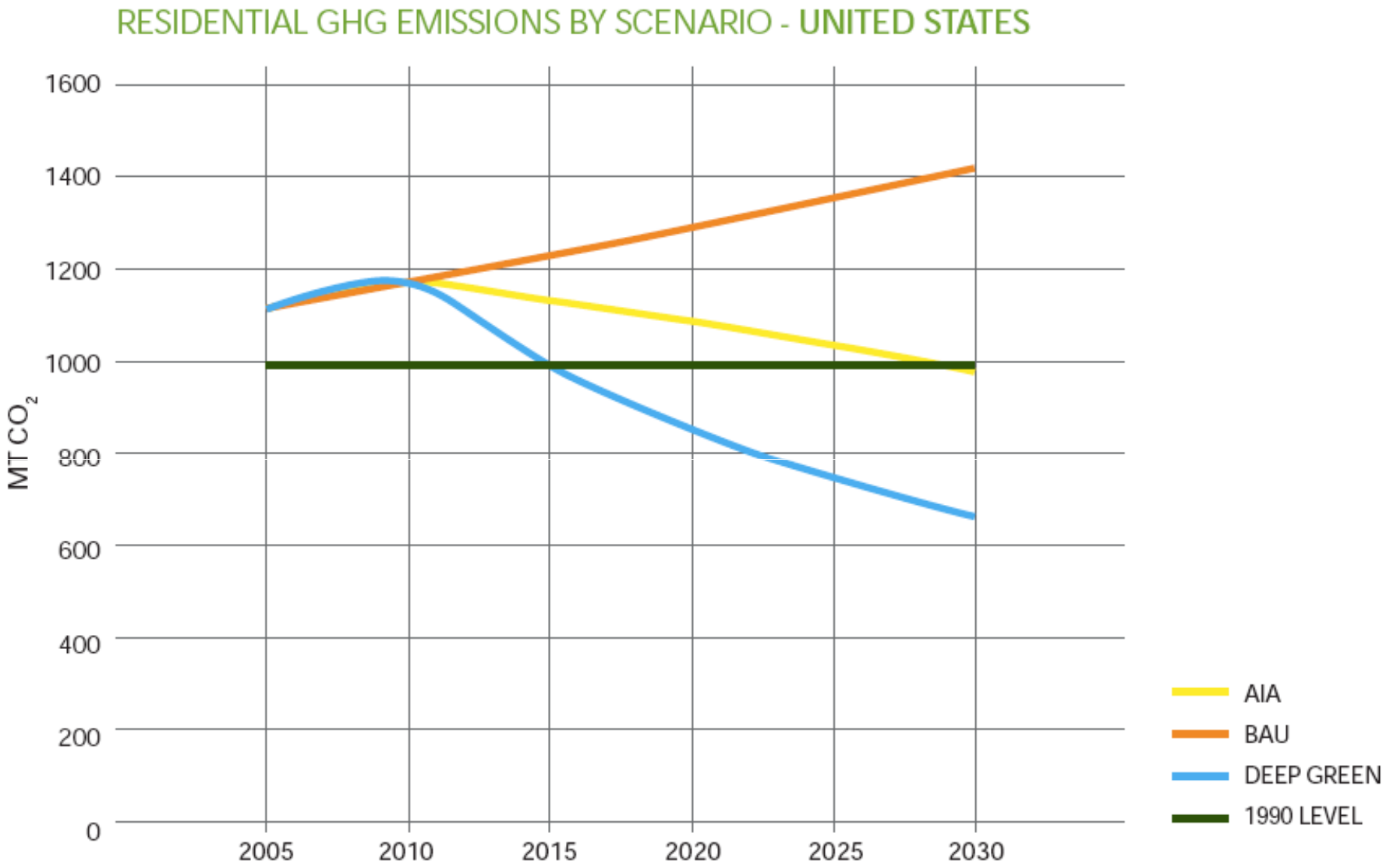

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Source: www.cec.org/greenbuilding/

"*To achieve the carbon reductions needed to prevent a global ecological catastrophe, almost every house in North America will need a deep energy retrofit.*" …

(Martin Holladay – Green Building Advisor)
August 2009

What Is a Deep Energy Retrofit?

- A DER brings an existing home up to current superinsulated home energy performance standards
- Typical component values are:
  - R-5 to R-10 slab
  - R-20 basement walls
  - R-30 to R-40 wall
  - R-40 to R-60 roof
  - Triple glazing
  - Air tight construction < 0.15 CFM50 per sf of shell
  - Mechanical ventilation
  - Right-sized, high efficiency mechanical systems

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Benefits of Deep Energy Retrofits

Adapted from: Moving Existing Homes Toward Carbon Neutrality
ACI July 2007 Summit White Paper

- Reduces GHG emissions
- Energy cost savings
- Increases long term affordability
- Increases passive survivability
- Maintains embodied energy
- Improves durability, IAQ, comfort, health and safety
- Increases the impact of investment in renewables
- Builds local economies
- Creates good jobs that cannot be out-sourced
- Stimulates product development
- Builds energy independence for US/Canada

www.affordablecomfort.org/event/aci_summit_moving_existing_homes_toward_carbon_neutrality/resources/29

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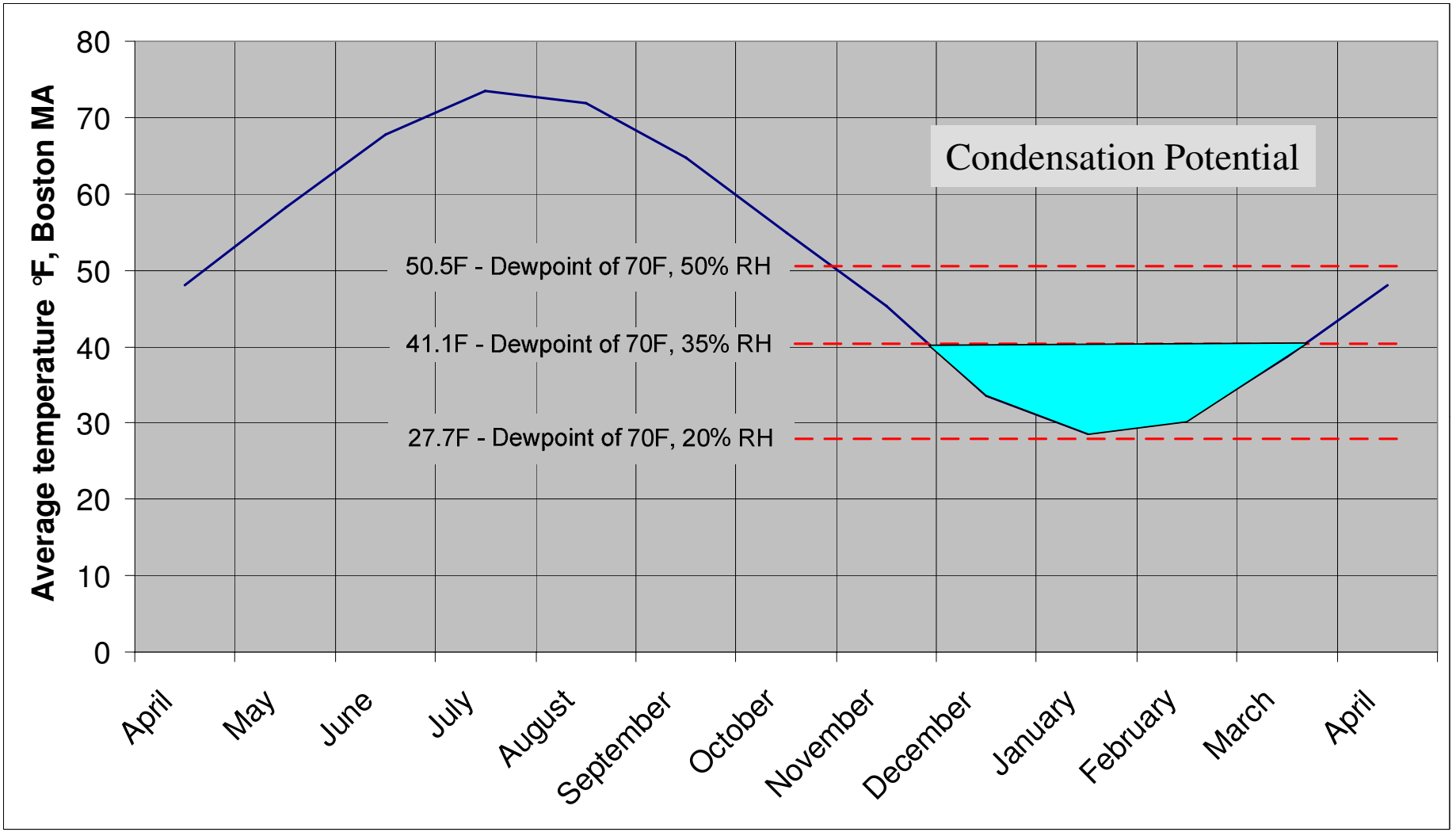
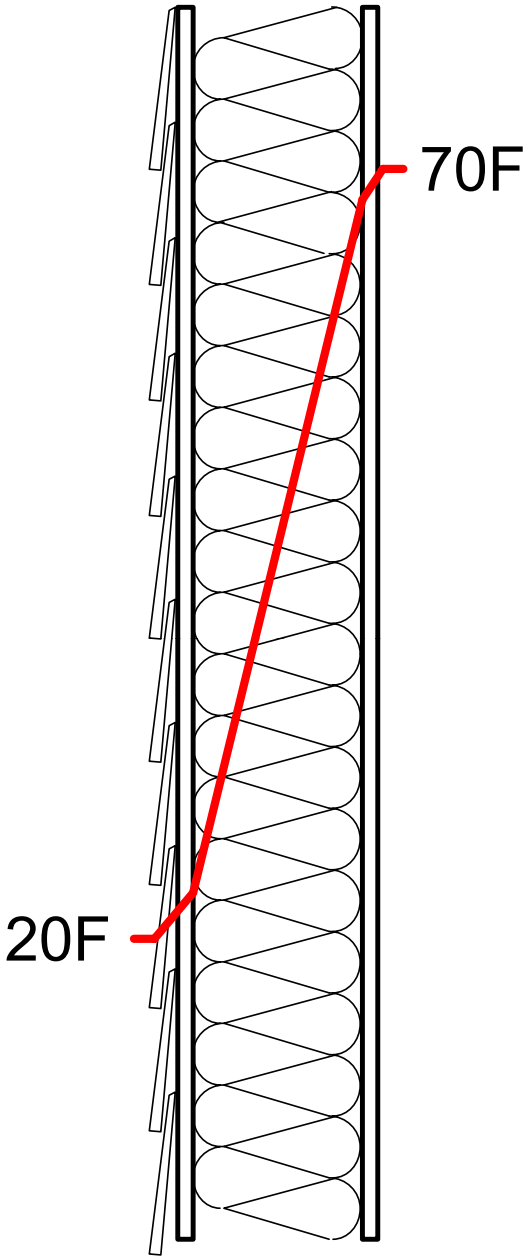
There are many ways to do a DER; we will focus on the exterior insulation approach because it offers the following advantages:

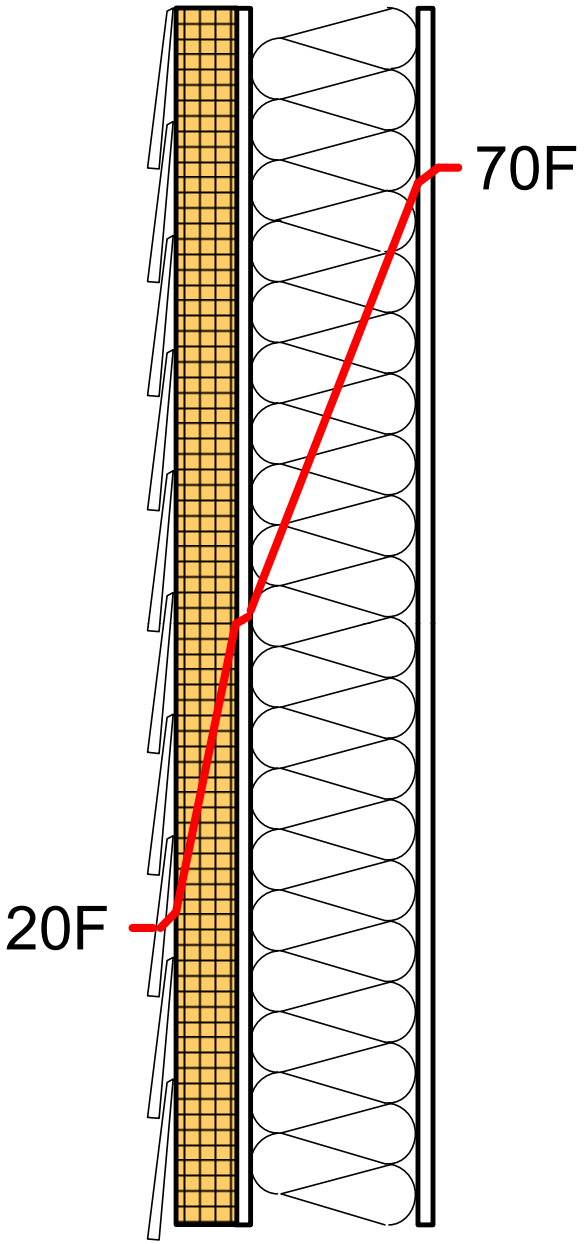
- Allows continuous, un-bridged insulation layer
- Facilitates exterior air barrier installation
- Can be installed while the home is occupied
- Thickness of insulation is not limited by wall thickness
- Eliminates the problems caused by blocking, bracing and other internal framing elements causing missed (un-insulated) wall cavities


Condensation Potential
Average temperature °F, Boston MA
80
70
60
50
40
30
20
10
0
50.5F - Dewpoint of 70F, 50% RH
41.1F - Dewpoint of 70F, 35% RH
27.7F - Dewpoint of 70F, 20% RH
April
May
June
July
August
September
October
November
December
January
February
March
April

Temperature gradient across a wall



- Note that the temperature of the interior face of the sheathing is 20F – well below the dewpoint of the inside air.
- If air from the inside reaches the sheathing in any significant amount, condensation will occur.
- Air leakage through a small hole can move 100 times more water into a building cavity than is transported by vapor diffusion, so air barriers (AB) are more critical than vapor diffusion retarders (VDR)
- With 2 inches of polyiso at R-13 the interior face of the sheathing is 41F – little condensation risk.



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Roofs – To Vent or Not To Vent?

- Traditionally, roofs were vented to allow moisture coming from the conditioned space to escape, and to prevent ice dams.
- Control of unwanted air movement is the primary defense against both moisture problems and ice dams.
- If a vented roof has air leaks that allow conditioned air to reach the vent spaces while snow is present, ice dams occur.
- Unvented roofs that are airtight and built to a true R-40 will not have ice dam problems (note that any roof under certain conditions, usually involving sun, can develop minor icicles.)
- The roof venting decision should take into account the exposure to wind-driven rain and snow and risk of wetting from outside, and the complexity of the roof (hips & valleys).
- Vent spaces should be two inches deep.

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Updated RC of NYS (2010):

R806.4 Unvented attic assemblies. Unvented attic assemblies (spaces between the ceiling joists of the top story and the roof rafters) shall be permitted if all the following conditions are met:

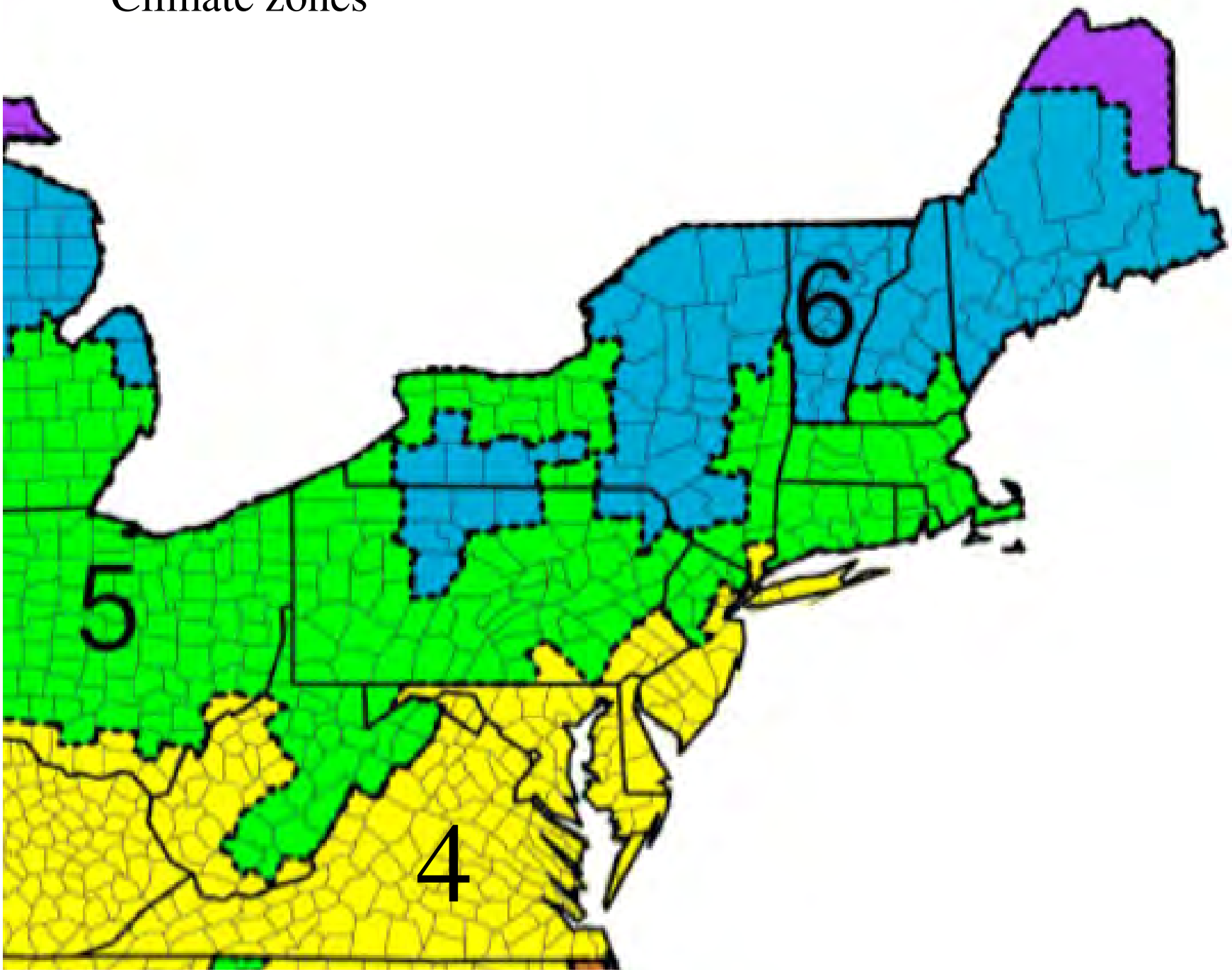
1. The unvented attic space is completely contained within the building thermal envelope.
2. No interior vapor retarders are installed on the ceiling side (attic floor) of the unvented attic assembly.
3. Where wood shingles or shakes are used, a minimum ¼ inch (6 mm) vented air space separates the shingles or shakes and the roofing underlayment above the structural sheathing.
4. In climate zones 5, 6, 7 and 8, any air-impermeable insulation shall be a vapor retarder, or shall have a vapor retarder coating or covering in direct contact with the underside of the insulation.
5. Either Items a, b or c shall be met, depending on the air permeability of the insulation directly under the structural roof sheathing.
   a. Air-impermeable insulation only. Insulation shall be applied in direct contact to the underside of the structural roof sheathing.
   b. Air-permeable insulation only. In addition to the air-permeable installed directly below the structural sheathing, rigid board or sheet insulation shall be installed directly above the structural roof sheathing as specified in Table R806.4 for condensation control.
   c. Air-impermeable and air-permeable insulation. The air-impermeable insulation shall be applied in direct contact to the underside of the structural roof sheathing as specified in Table R806.4 for condensation control. The air-permeable insulation shall be installed directly under the air-impermeable insulation.

Table R806.4 Add new table to read as shown: (RB269-06/07)

TABLE R806.4
INSULATION FOR CONDENSATION CONTROL

CLIMATE ZONE	MINIMUM RIGID BOARD OR AIR-IMPERMEABLE INSULATION *R*-VALUE [A]
2B and 3B tile roof only	0 (none required)
1, 2A, 2B, 3A, 3B, 3C	R-5
4C	R-10
4A, 4B	R-15
5	R-20
6	R-25
7	R-30
8	R-35

Climate zones



Air Leakage Consequences

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Air Barriers

An air barrier is a critical part of a superinsulated house. It is a system of materials that control air flow through the building enclosure. It needs to be:

- Impermeable to air
- Continuous
- Strong enough to resist forces on it
- Durable

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- Air barrier issues are integrally related to a fundamental question in DERs - where is the additional insulation going - inside, within, or outside of the existing assemblies?
- Adding insulation to the exterior of a building usually makes it easier to achieve a functional air barrier.
- Adding insulation to the interior of a building makes it more challenging to achieve a functional air barrier, because partition walls and floors penetrate this new air barrier. In a gut rehab this is easier, because the structure is exposed.
- Challenging locations include:
    - Rubble foundations
    - Wall/foundation joints
    - Wall/roof joints - at overhangs and at parapets
    - Walls with board sheathing
- As in new construction, all penetrations (pipes, wires, chimneys, hatches) should be sealed. Caulk, foam sealant, and sheet metal are all likely to be applicable.

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Installing air barriers

- Air barriers require consistency and attention to detail.
- Good planning is essential
- Tenacity and creativity are vital in retrofit situations
- Any laborer with attention to detail, tenacity and creativity can install an air barrier. High levels of skill/training are not needed ***IF*** a good plan is in place.
- It is okay to have multiple air-barriers (layers)in an assembly, but doing so will be a waste of time if either is not complete.

Testing Air Tightness

- Air tightness is tested with a blower door, which depressurizes the building with a calibrated fan and measures how much air flow is needed to depressurize the building to 50 Pascals negative with respect to outdoors (CFM50).
- A blower door can also be used effectively to locate areas of leakage. Either a smoke pencil or a theatrical fog machine can be used to make the leakage visible. An infrared (IR) camera also works well to visualize leakage, especially if the building is scanned before the blower door is run, then after it has run for 10 - 20 minutes.
- Seal leaks, re-test, and watch for re-routing of the leak through a new path.

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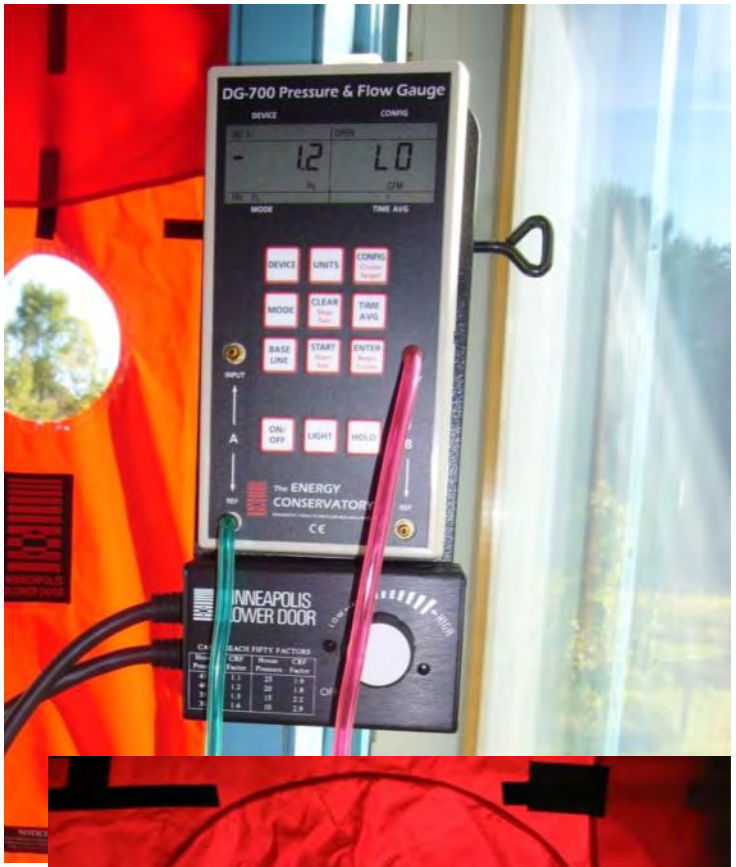
Blower Door


DG-700 Pressure & Flow Gauge
DEVICE
CONFIG
- 12
LO
MODE
TIME AVG
DEVICE
UNITS
CONFIG
MODE
CLEAR
TIME AVG
BASE LINE
START
ENTER
INPUT
ON/ OFF
LIGHT
HOLD
The ENERGY CONSERVATORY
INNEAPOLIS
OWER DOOR

Finding the leaks

Smoke pencil

Fog machine

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Thermal bridges

- A thermal bridge is wherever the structure of the building (or other material) penetrates through the insulation layer. It compromises insulating value.
- The effect is larger as the difference between the insulating value of the two materials increases.
- Steel, aluminum, and masonry need to be completely inside or outside the thermal envelope.

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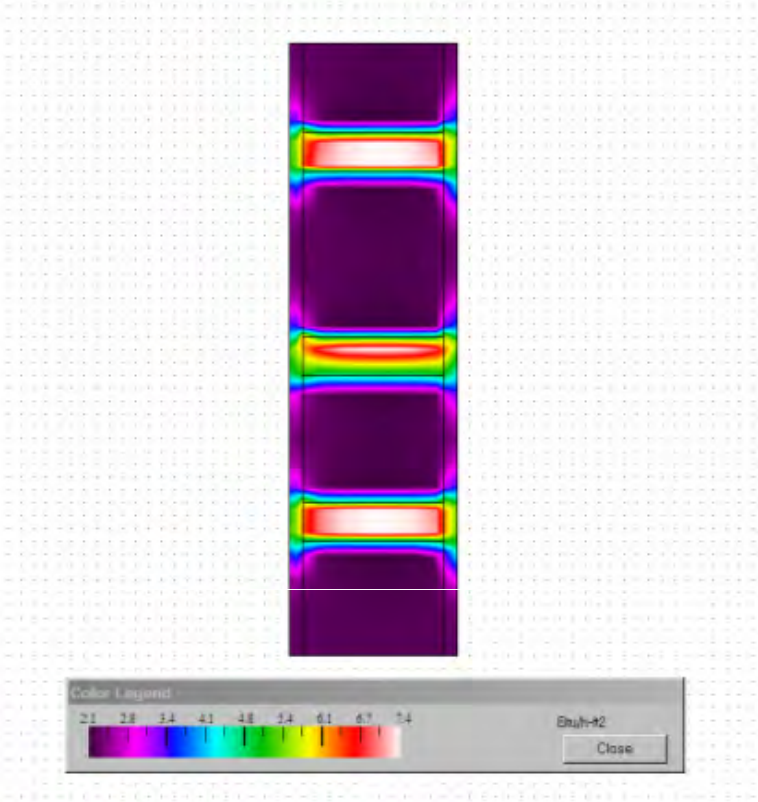
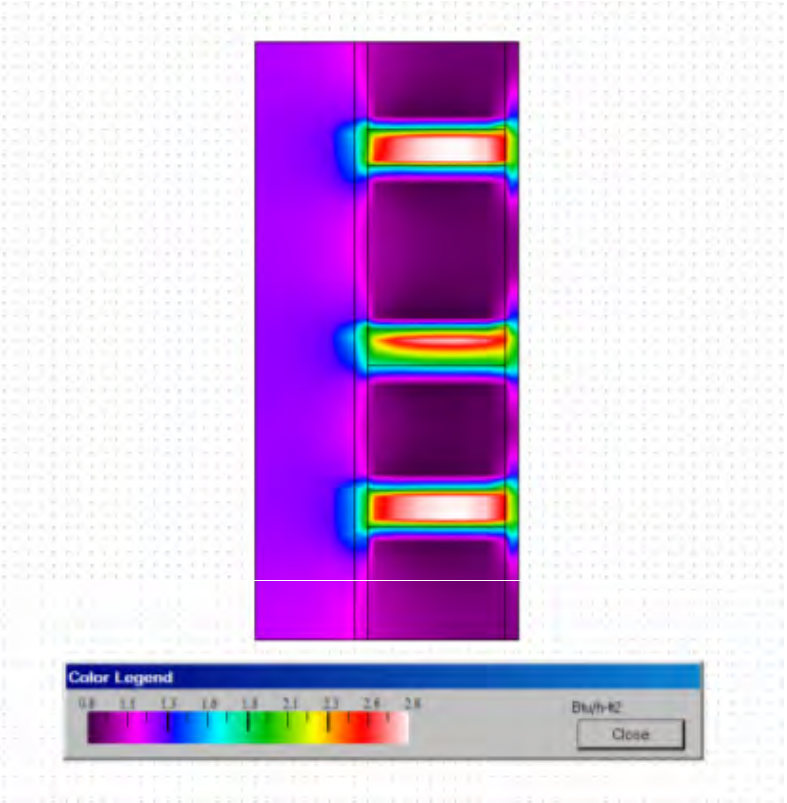
Heat flow and R values in walls



2x6 SPF 18% wood
Nominal R=35.0 ,
Actual R=20.3 (58% of nominal)



2x6 cellulose 18% wood 4" SPF
Nominal R= 46.0,
Actual R=41.0 (90% of nominal)

Note :
- heat flux scales are different for each case!
- foam (SPF) ON the wall is much more effective than foam IN the wall

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Single Family Home near Troy, NY (< 12 yrs old)

The housing stock addressed:

- 100+- Year old
- Wood Balloon frame
- Crenelated masonry block foundations
- Damp to wet foundations, but not regularly flooding
- Simple footprint
- Few additions, porches or bumpouts
- In need of siding, roofing or both

The Retrofits from Utica, NY

- The Homes treated
- Below Ground Work – Foundations
- Above Ground Work – Exterior walls
- Attic/Roof Strategies
- Mechanical Systems

DRP 3_4

DRP 1

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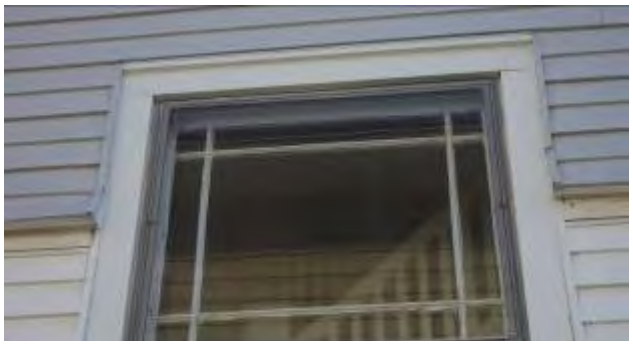

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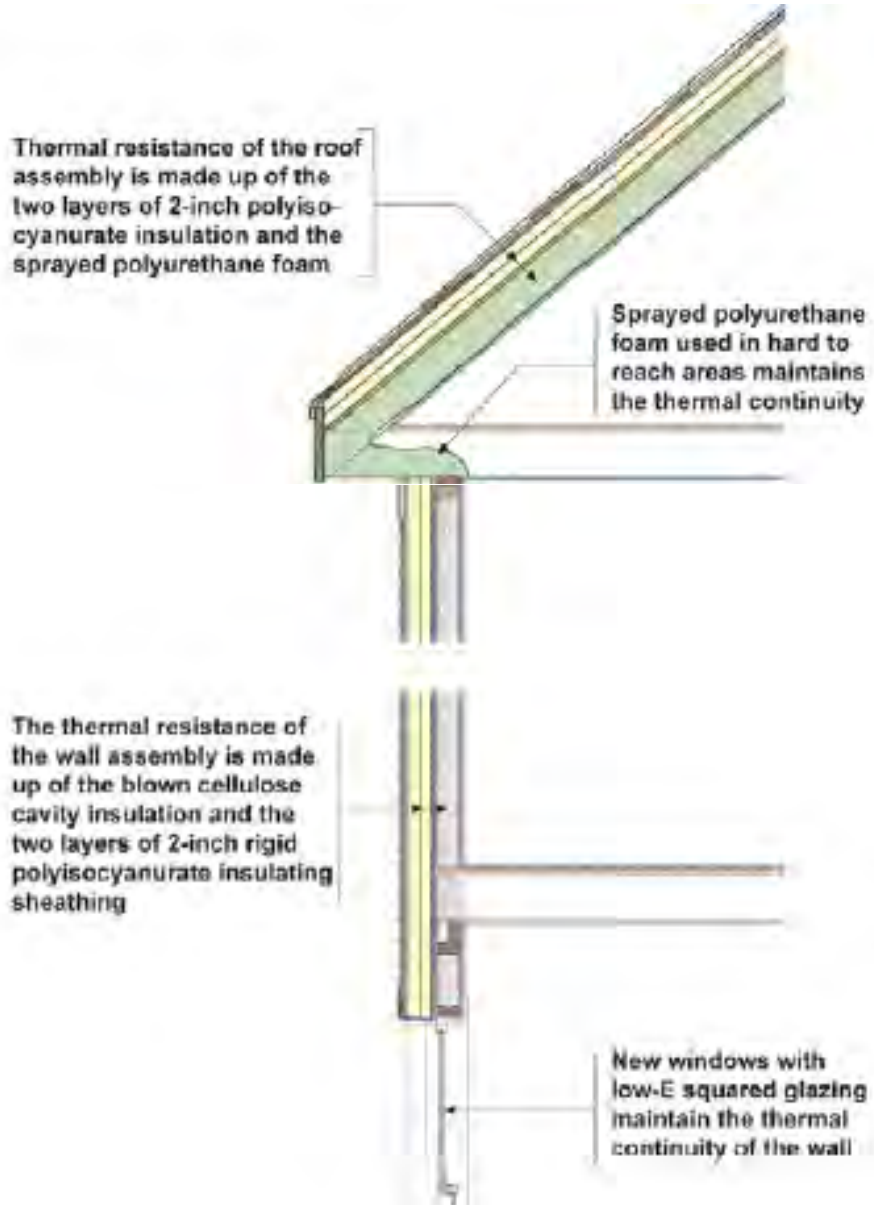
The Retrofit Energy Model, Existing to DER

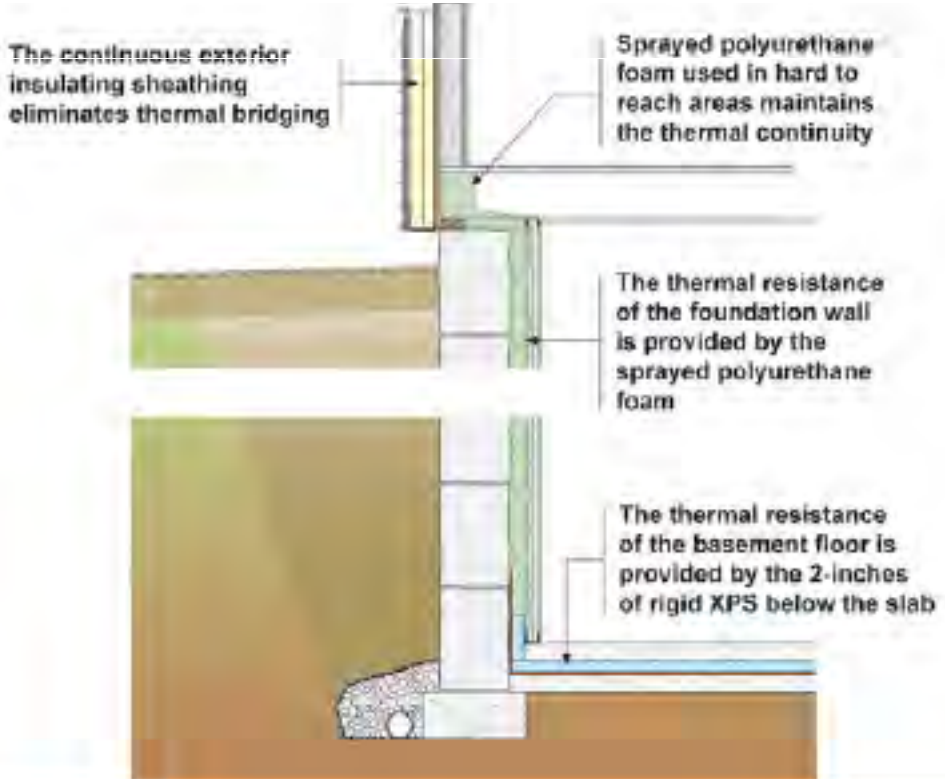
- No insulation to R-5 slab
- No insulation to R-23 basement walls
- No insulation to R-31 walls
- No insulation to R-45 roof
- Add a low-e storm to the replacement windows
- Air tightness improvement 4900 CFM50 to 750 CFM50
- Heat recovery ventilation
- High efficiency mechanicals

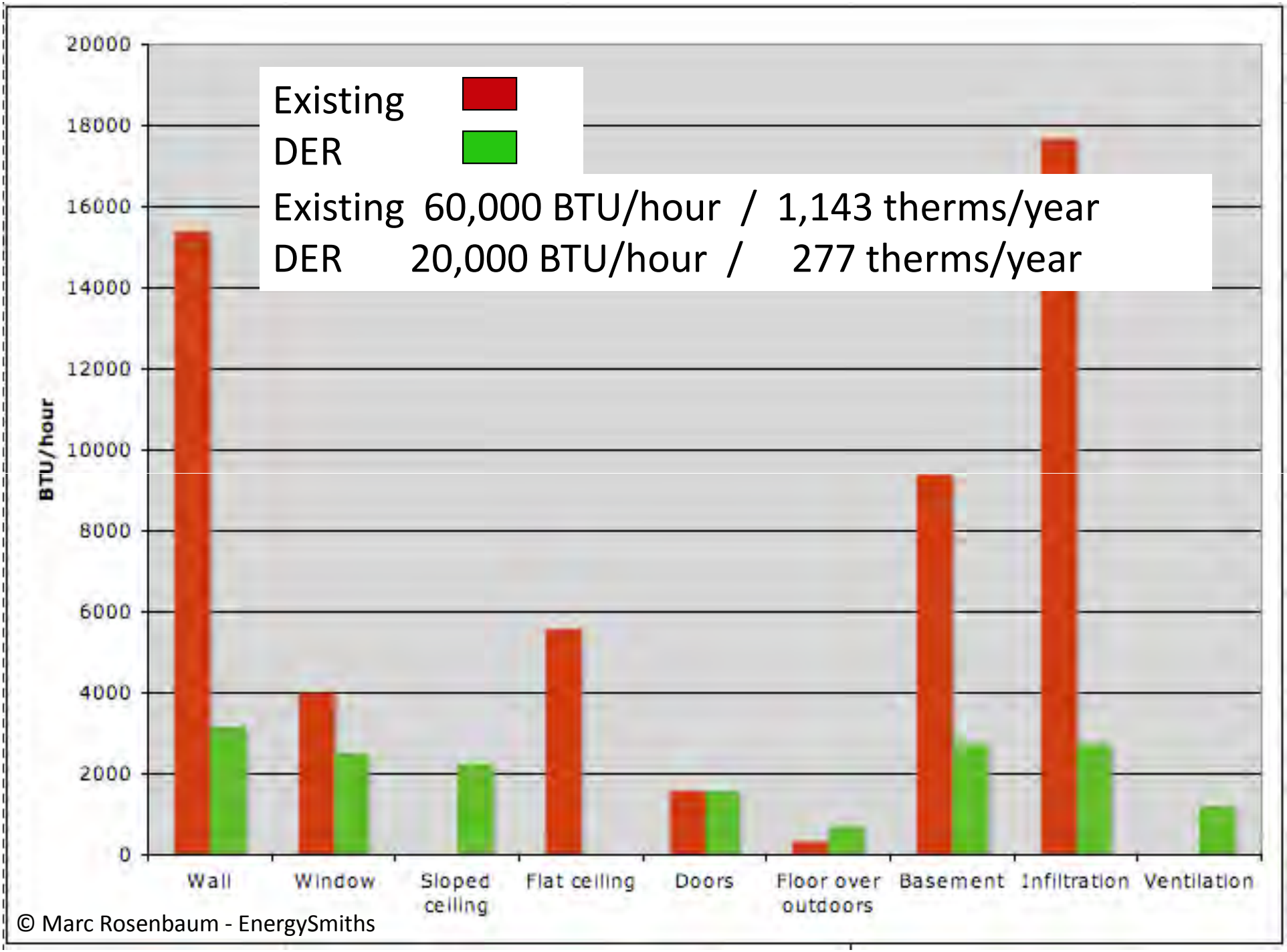
Drawings and photos courtesy of Building Science Corp.

Note continuity of AB, thermal barrier, drainage plane, and vapor management

Note that insulation to the ground is taken seriously.
To retrofit an existing slab, install insulation on top with a tile-backer board walking surface.







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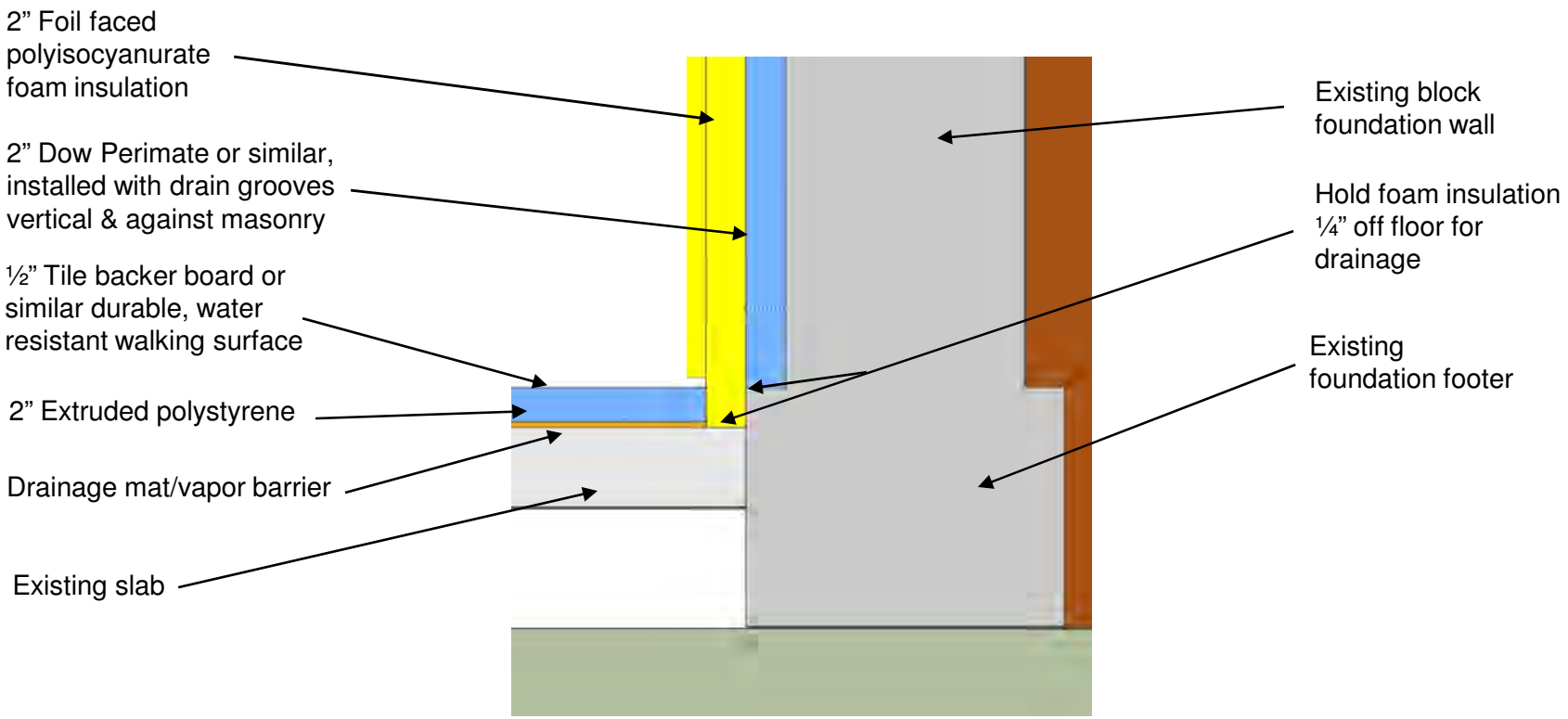
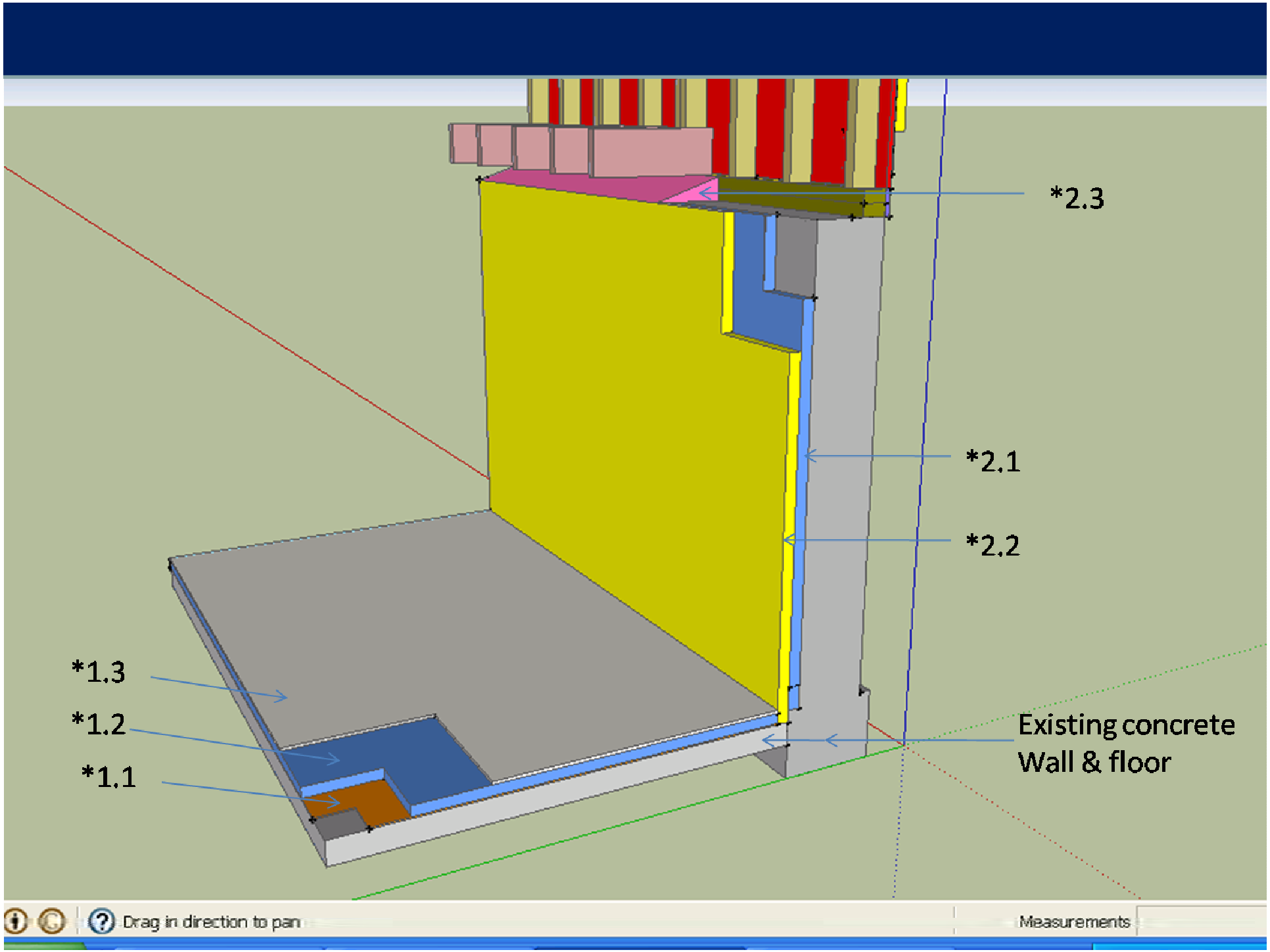
Below Grade Work

Slab-foundation wall detail
NYSERDA DEEP Energy Retrofit Pilot- Utica, NY
Prepared by Vermont Energy Investment Corporation
3/28/10



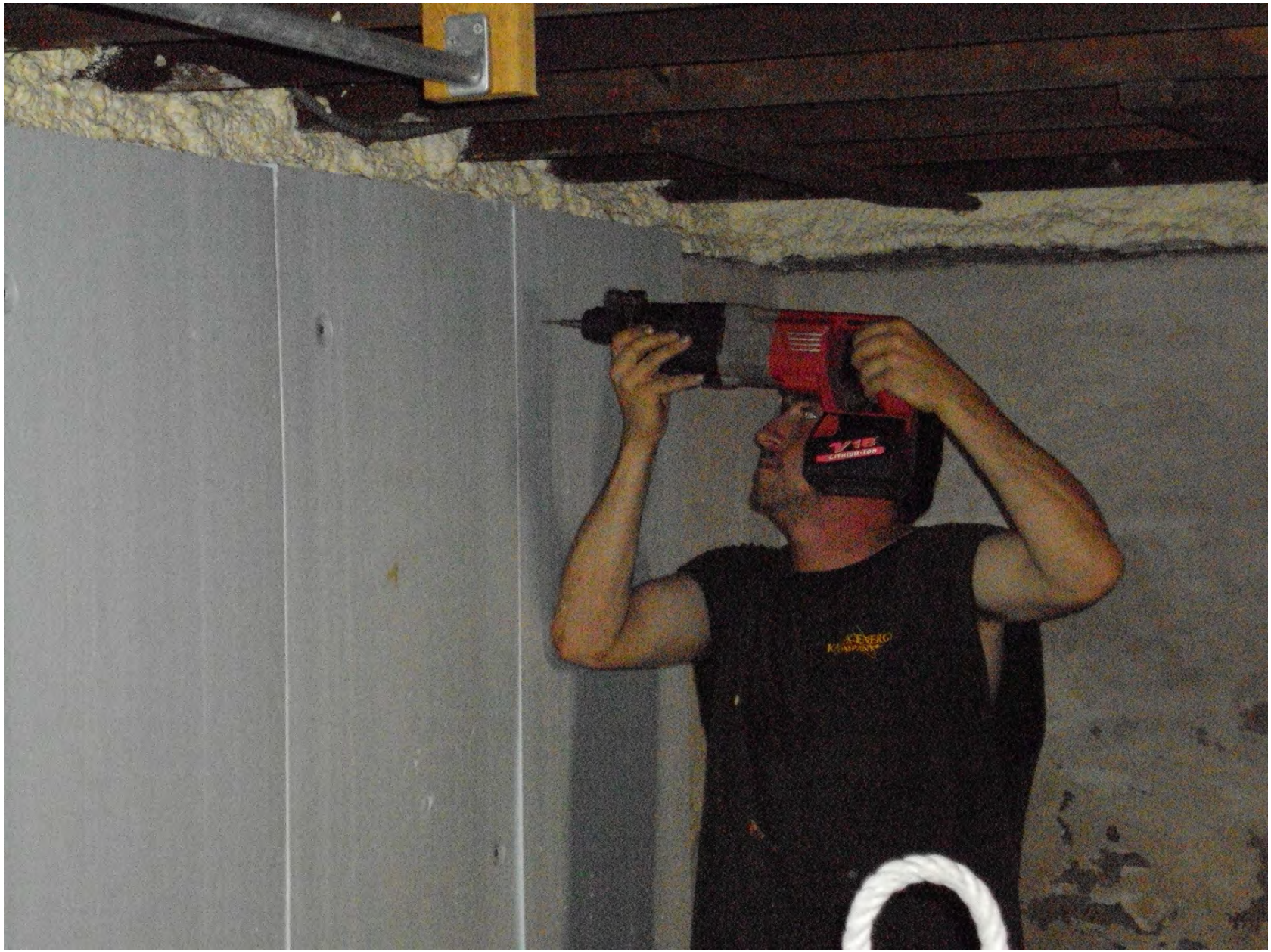

*2.3
*2.1
*2.2
*1.3
*1.2
*1.1
Existing concrete
Wall & floor
Drag in direction to pan
Measurements

07/05/2010

Foundation walls:

Before

After



07/13/2010

Dow Perimate.
Install with grooves against foundation to allow water drainage
07/05/2010

Rubble foundation

Band Joists

Before

After

DRP1 required additional drainage at the footers.

Structural Beams

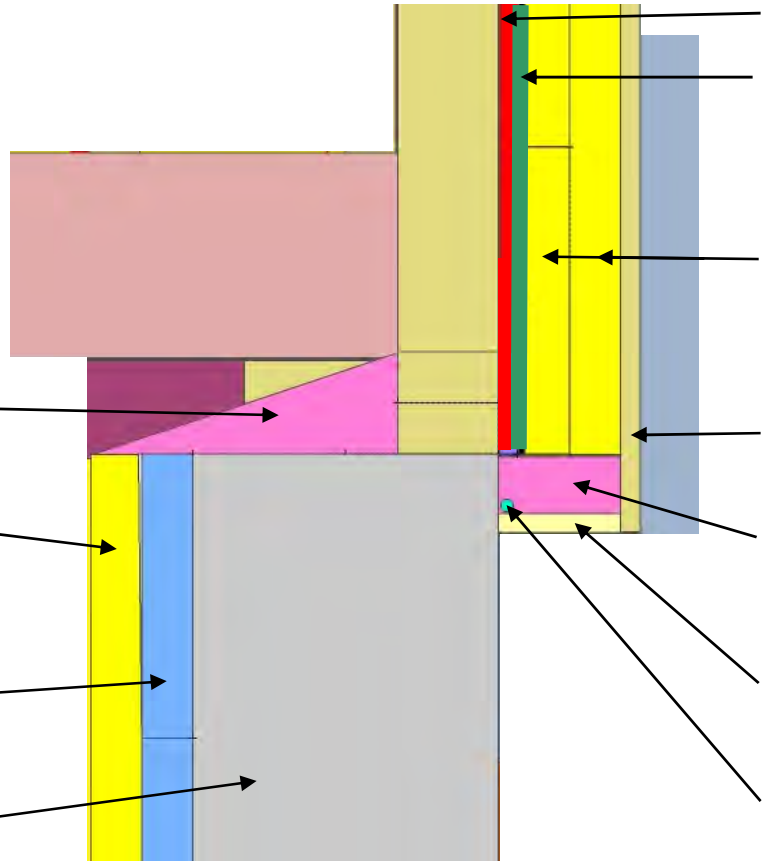
Wood in masonry

•Wood framing elements in contact with cold masonry have the potential for decay as moisture condenses on the cold wood.
•Interior foundation insulation makes the problem potentially worse
•Either cut the wood away from the masonry and support from inside the thermal boundary (with Lally column, etc)
•Or hold interior insulation 12” away from wood element to allow passive heating and drying of the wood (as it has for the life of the building so far)

Beam with insulation

Above Grade work

Exterior wall detail at foundation
NYSERDA DEEP Energy Retrofit Pilot- Utica, NY
Prepared by Vermont Energy Investment Corporation
4/1/10



Existing board sheathing

Exterior air barrier: Thermply or similar, all seams taped with foil tape

2 layers of 2” foil faced polyisocyanurate foam insulation, edges staggered and lapped

1 x 3 strapping installed vertically over existing wall studs

Spray foam sealant connecting Thermoply air barrier to foundation

1x bottom strap to contain foam and provide rodent barrier

Backer rod filling gap between rusticated block foundation wall and bottom strapping

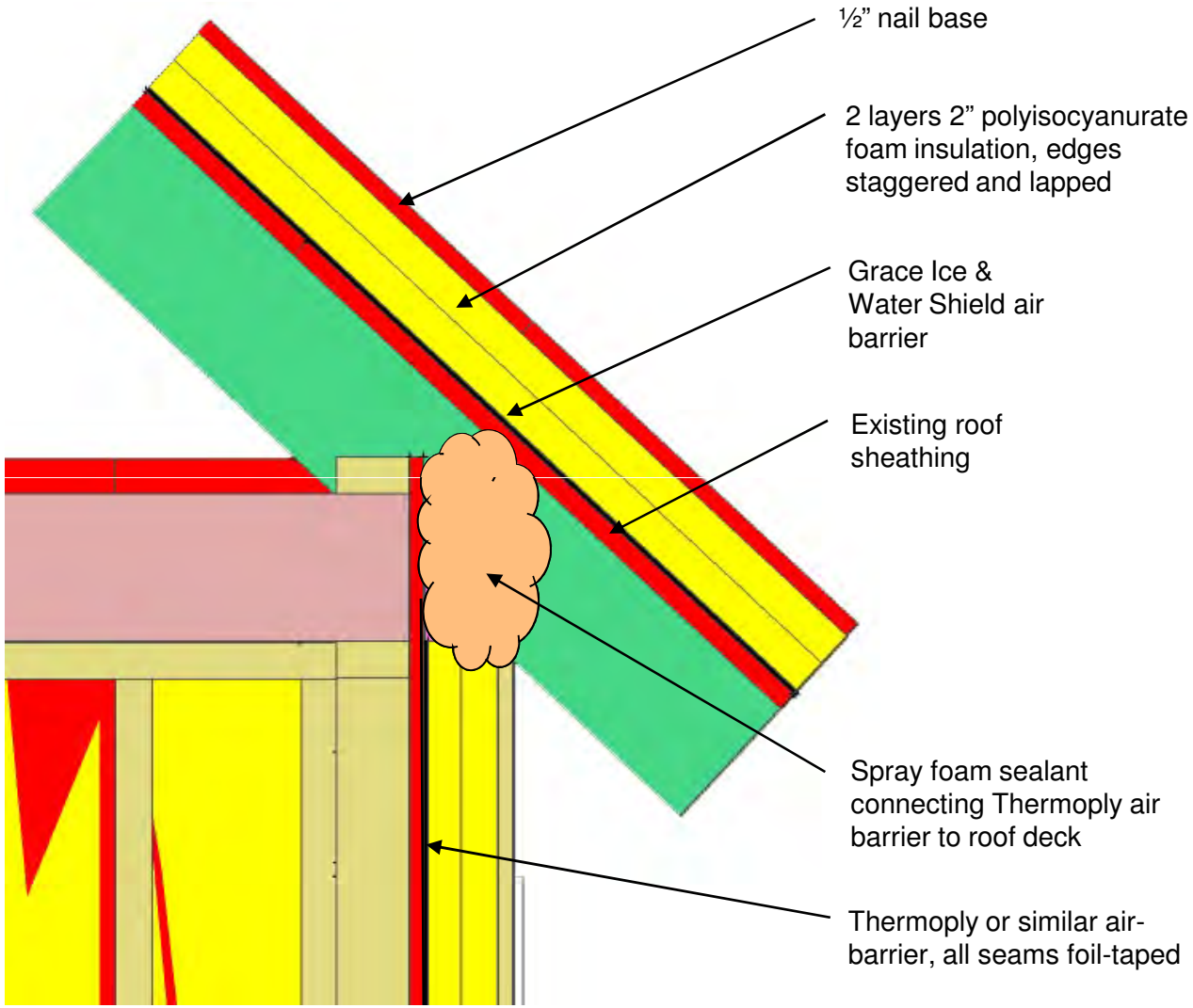
Spray foam sealant covering block wall cavity and connecting insulation to sill

2” foil faced Polyisocyanurate foam insulation, rated to be left exposed, seams taped airtight (see Thermax Exposed Basement Application document)

2” Dow Perimate or similar, installed with drain grooves vertical & against masonry

Existing rusticated block wall

Exterior wall to eave/roof detail
NYSERDA DEEP Energy Retrofit Pilot- Utica, NY
Prepared by Vermont Energy Investment Corporation
3/28/10



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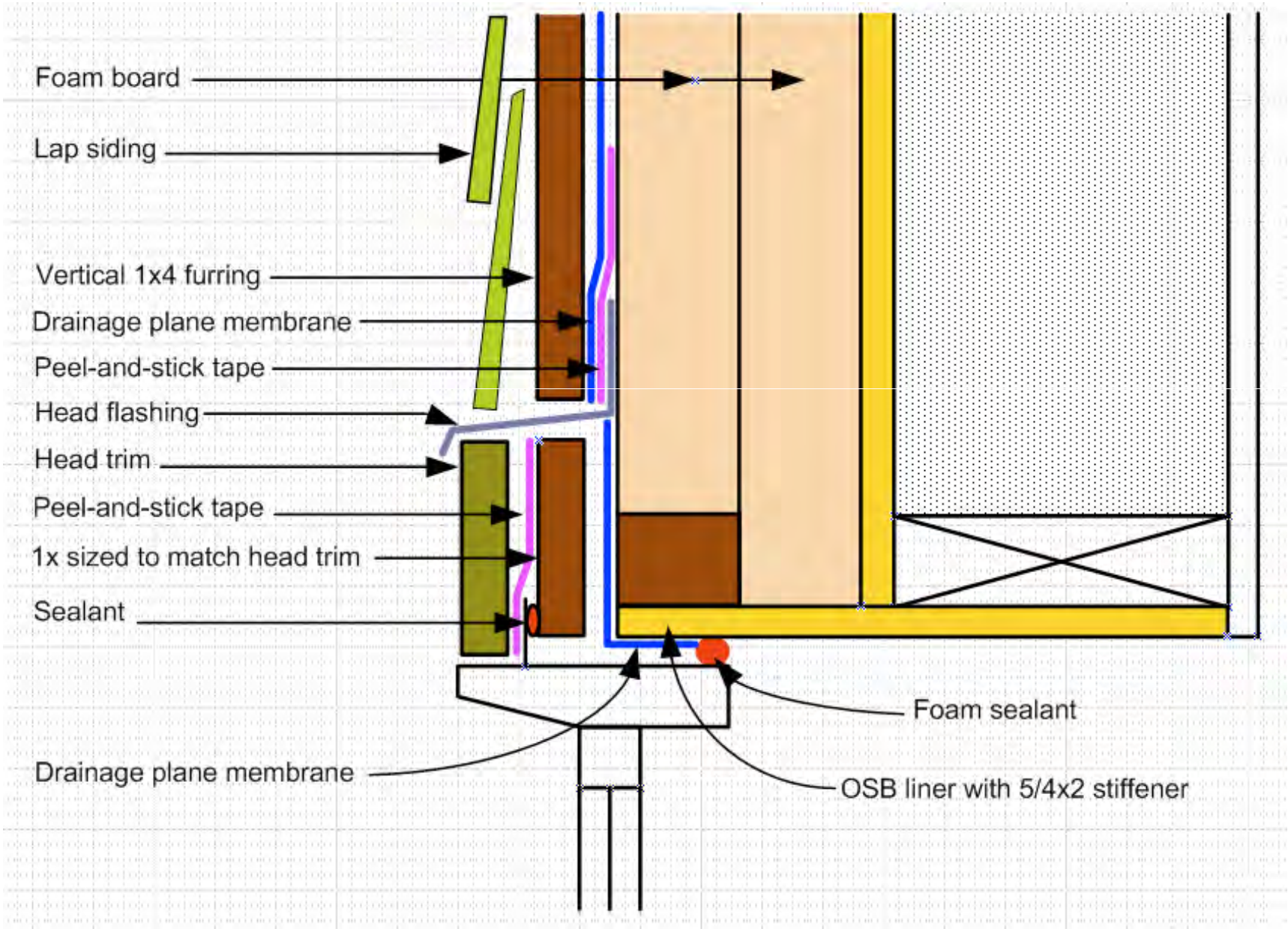
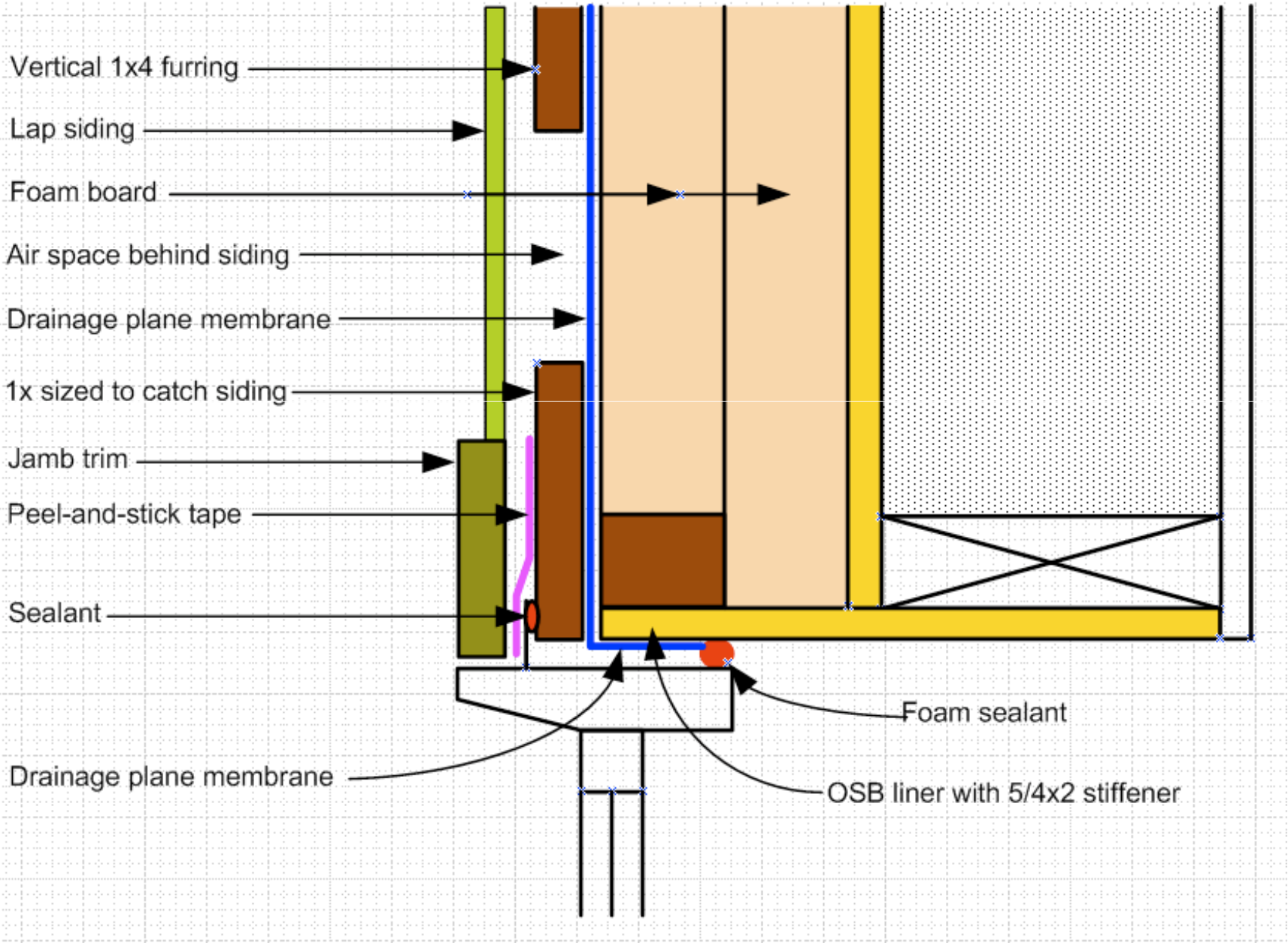
Window/Wall Installation Detail

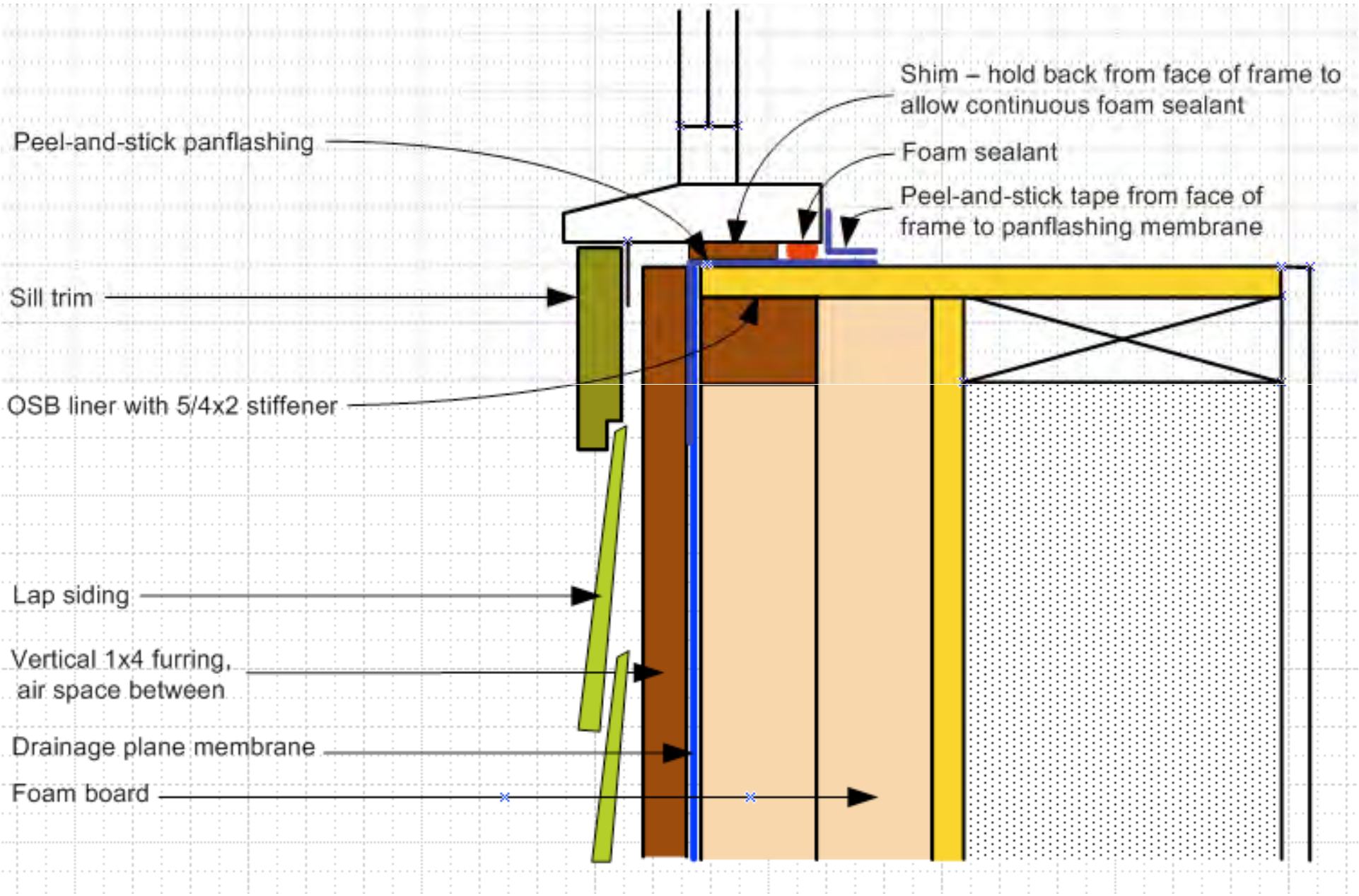
Window head

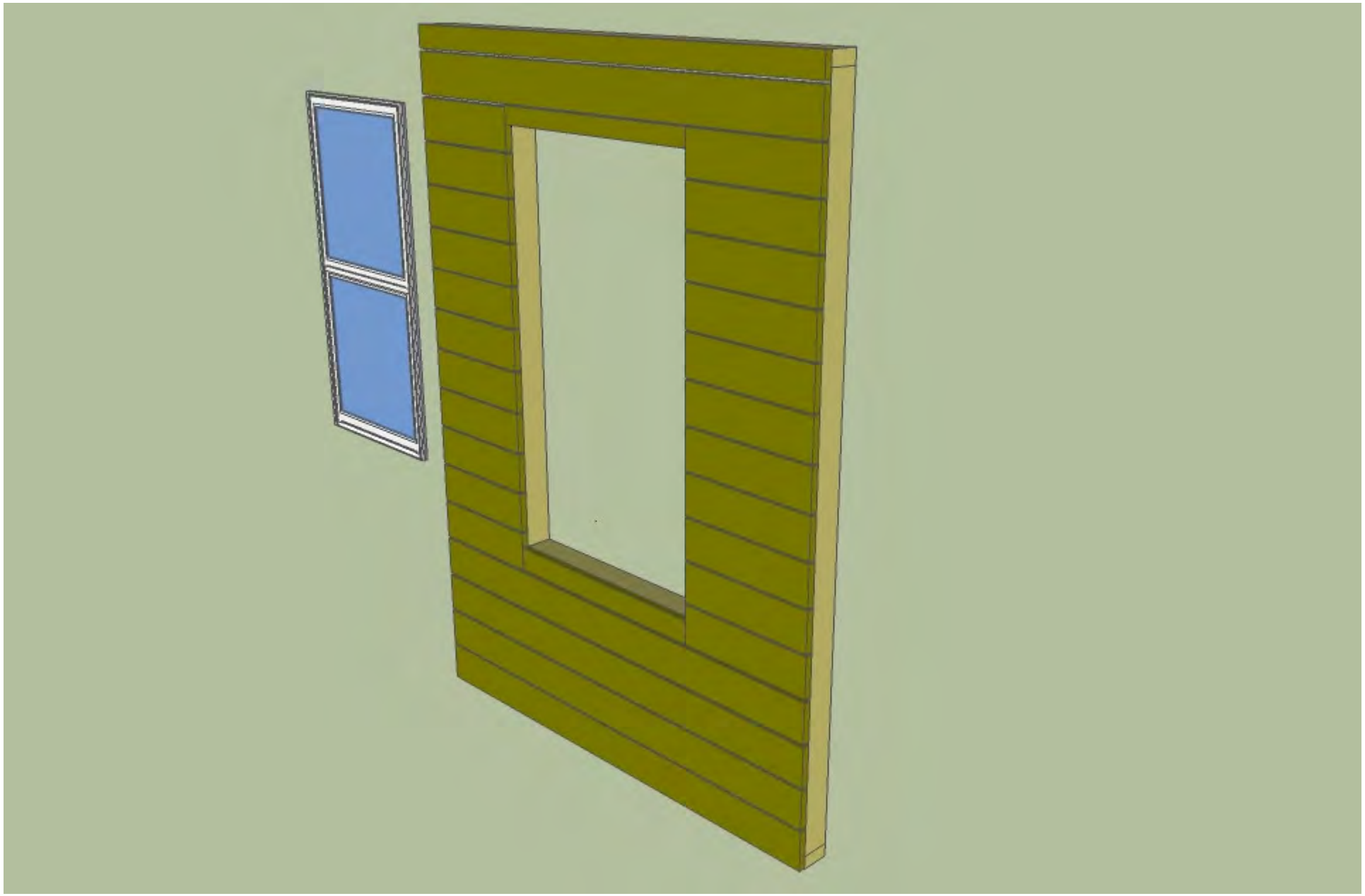

Foam board
Lap siding
Vertical 1x4 furring
Drainage plane membrane
Peel-and-stick tape
Head flashing
Head trim
Peel-and-stick tape
1x sized to match head trim
Sealant
Foam sealant
Drainage plane membrane
OSB liner with 5/4x2 stiffener

Window jamb

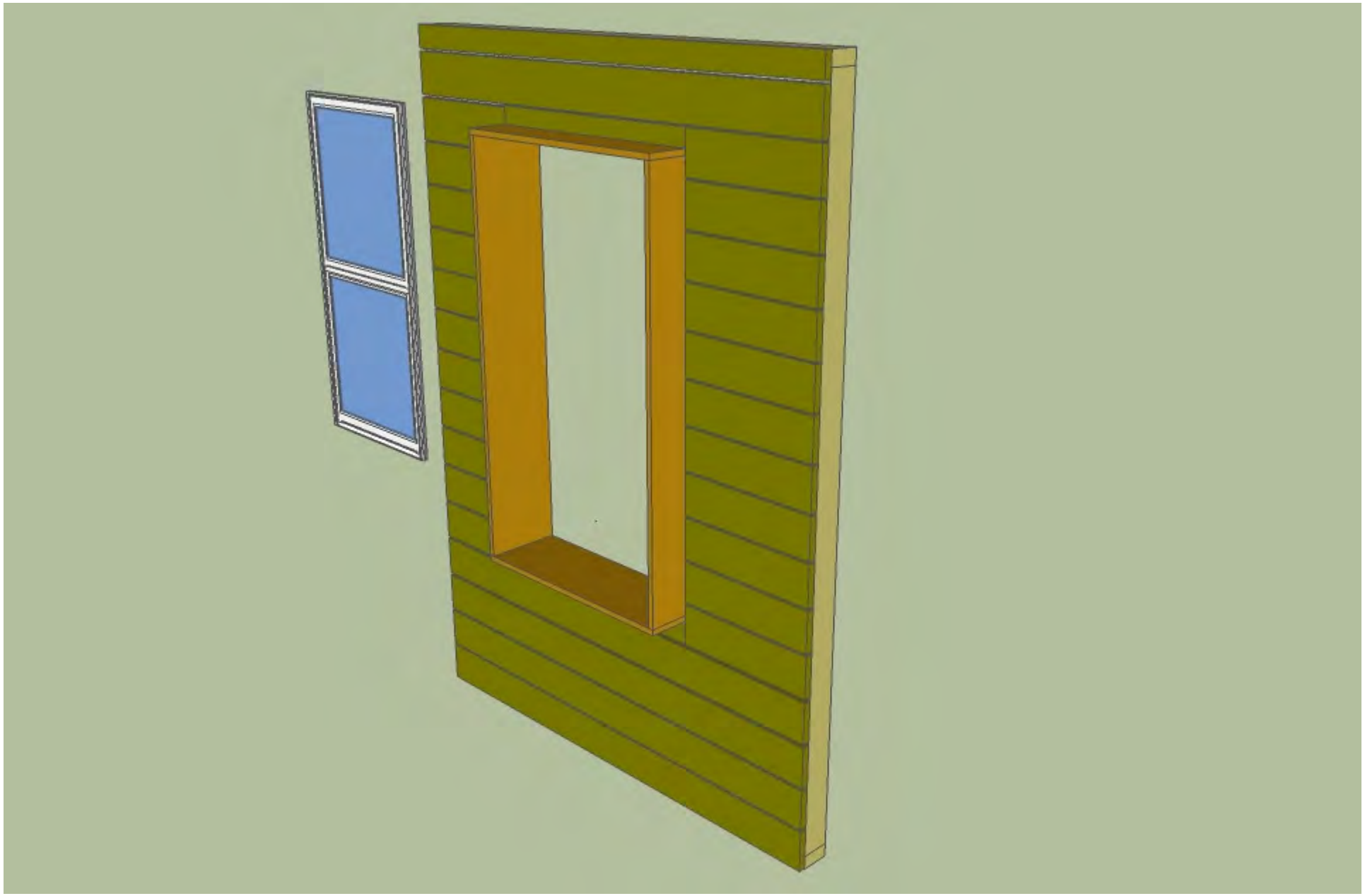

Vertical 1x4 furring
Lap siding
Foam board
Air space behind siding
Drainage plane membrane
1x sized to catch siding
Jamb trim
Peel-and-stick tape
Sealant
Foam sealant
Drainage plane membrane
OSB liner with 5/4x2 stiffener

Window sill

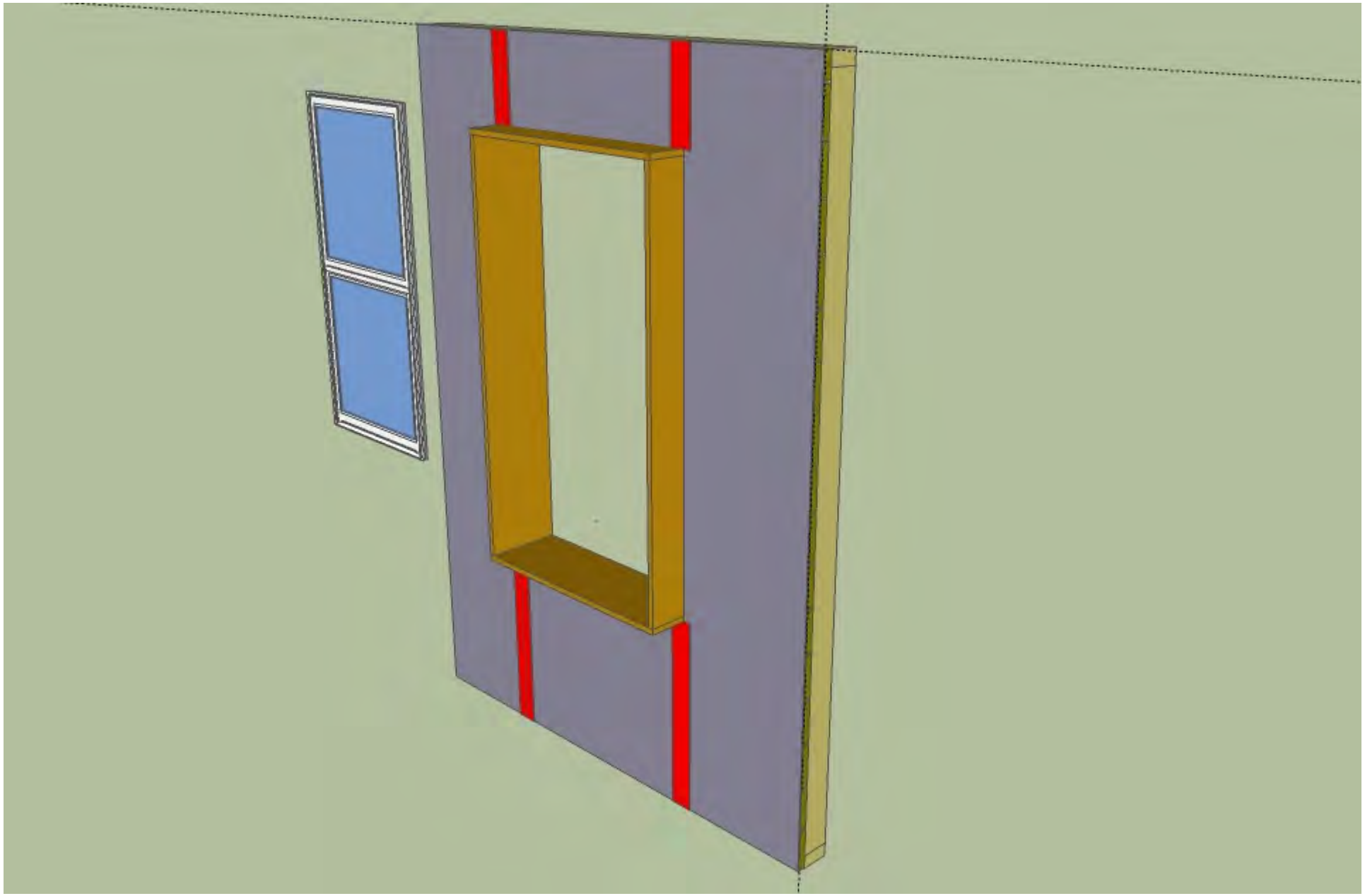

Shim – hold back from face of frame to allow continuous foam sealant
Peel-and-stick panflashing
Foam sealant
Peel-and-stick tape from face of frame to panflashing membrane
Sill trim
OSB liner with 5/4x2 stiffener
Lap siding
Vertical 1x4 furring, air space between
Drainage plane membrane
Foam board



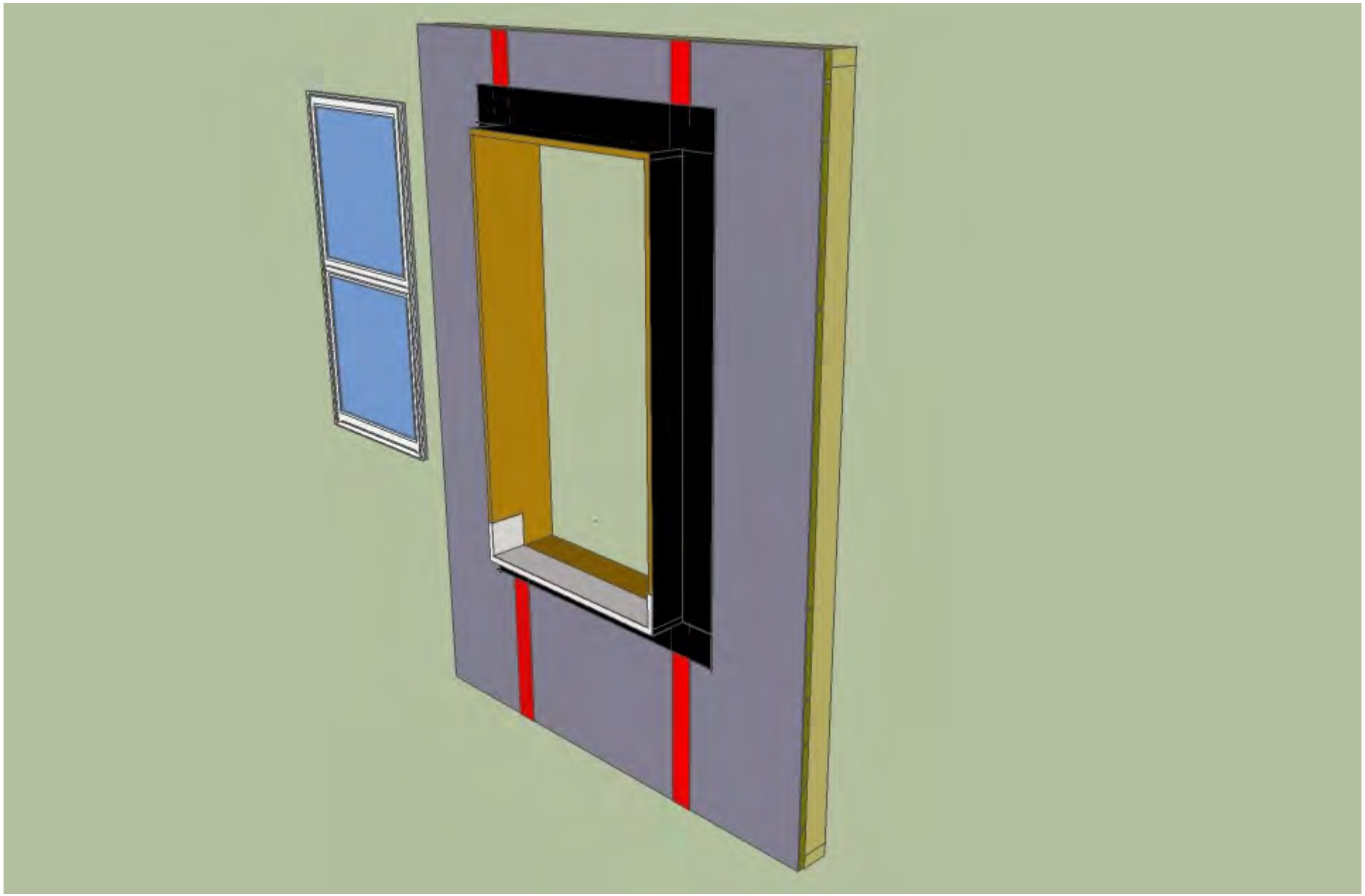
Existing wall framing and sheathing with old siding removed



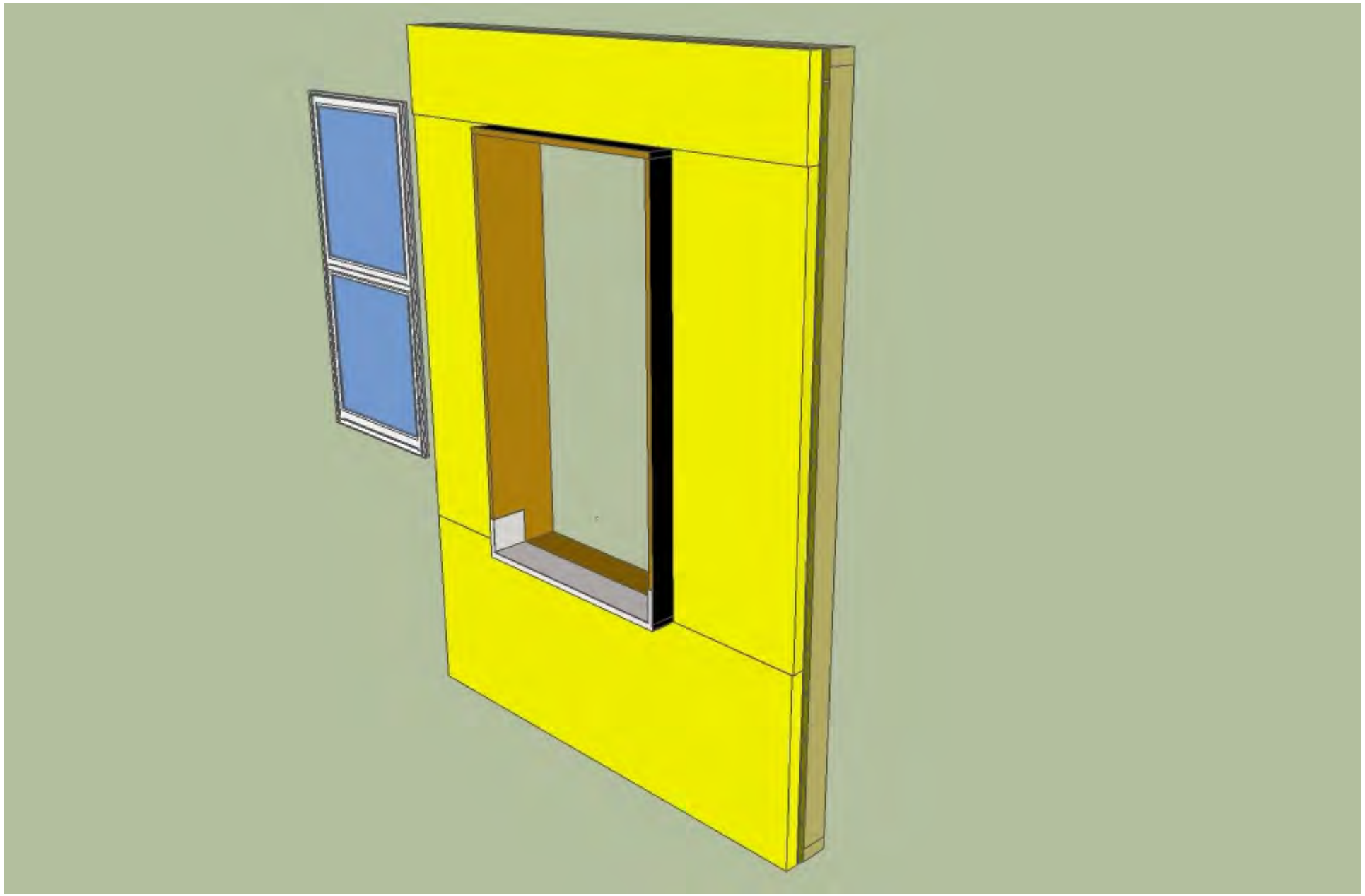
¾” Window buck installed



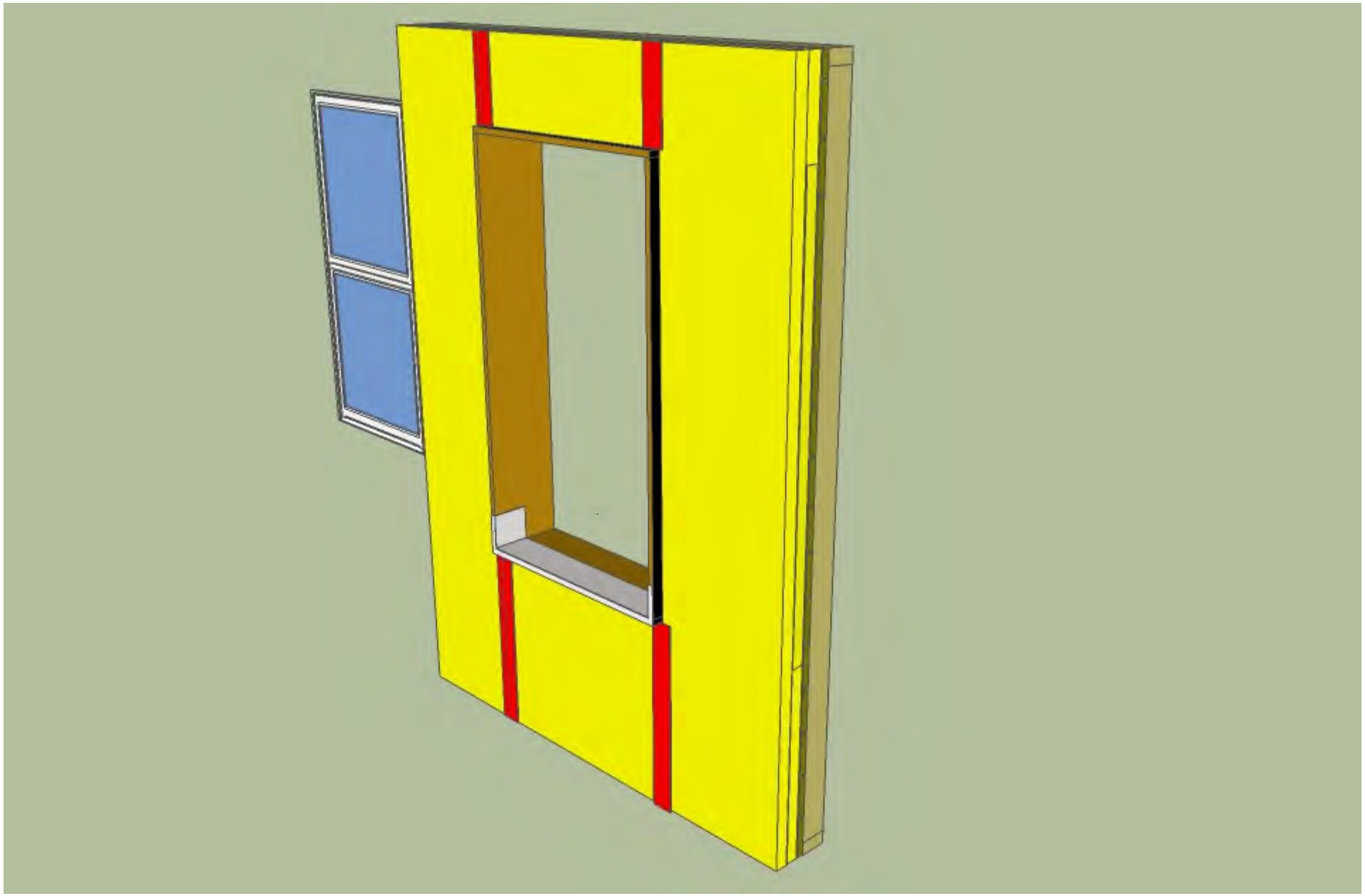
Exterior air-barrer installed, seams taped, edges caulked to sheathing



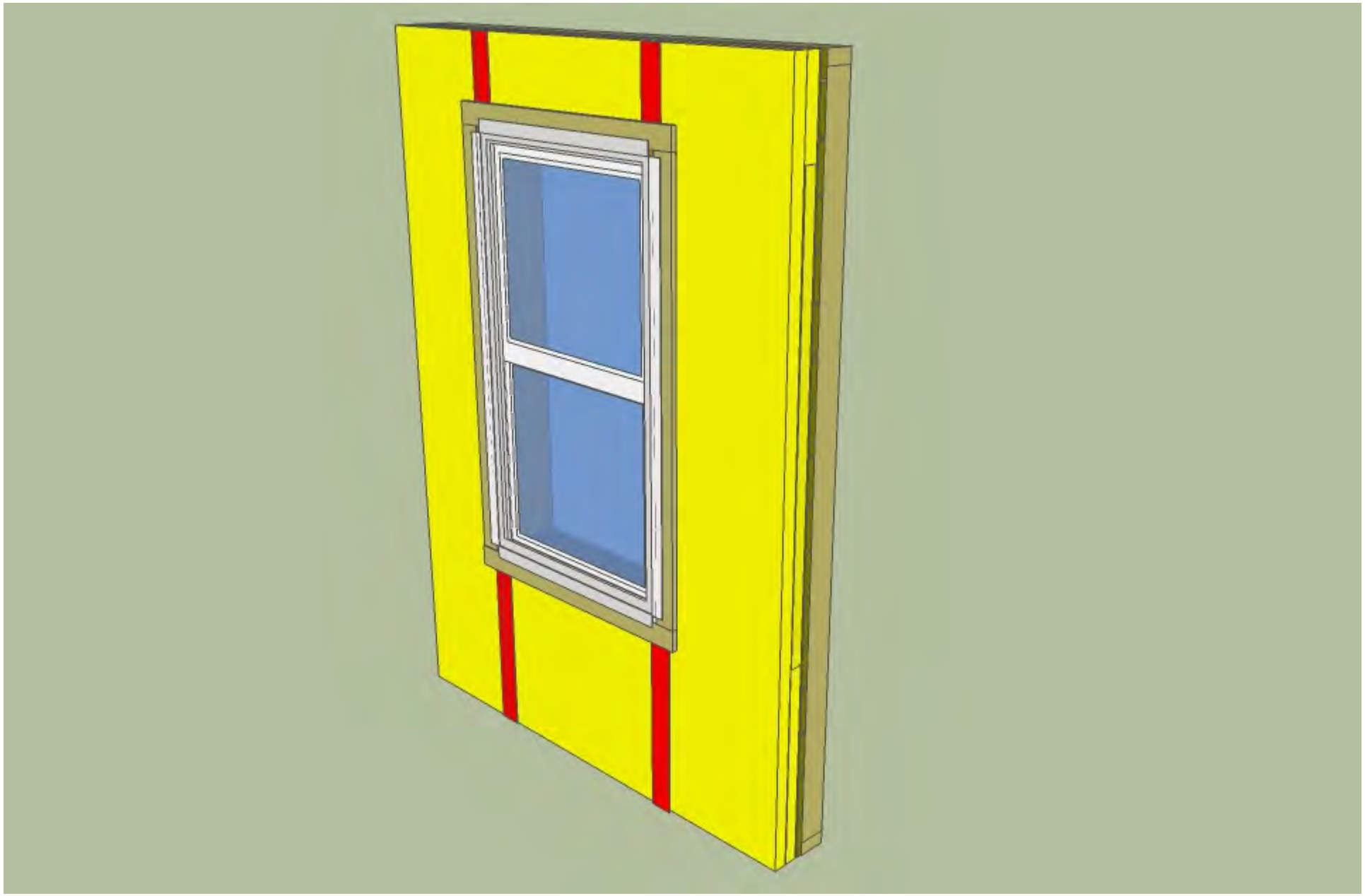
Window buck flashed with peel & stick membrane; sill pan-flashed



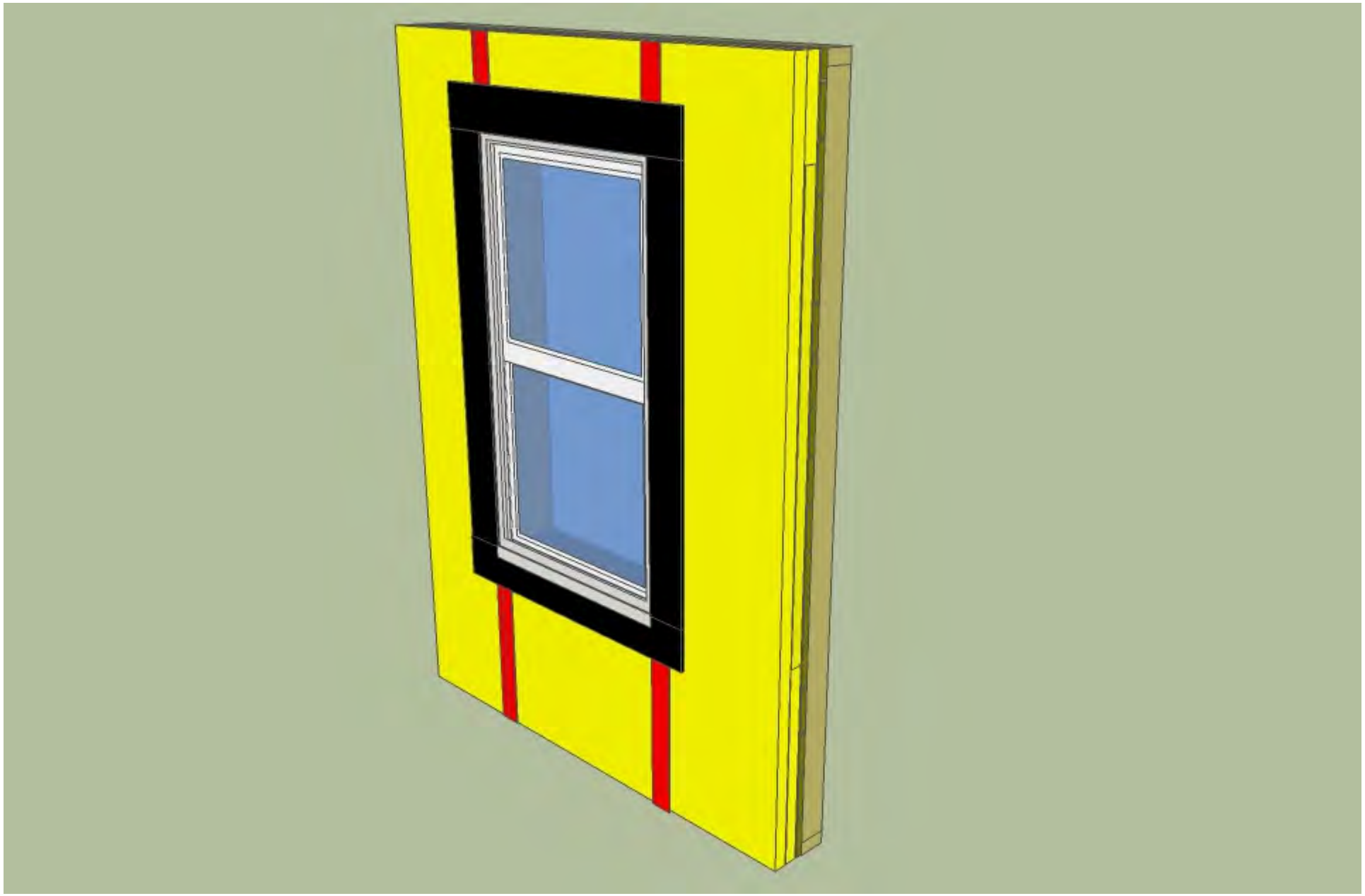
First layer of foil-faced polyisocyanurate insulation installed



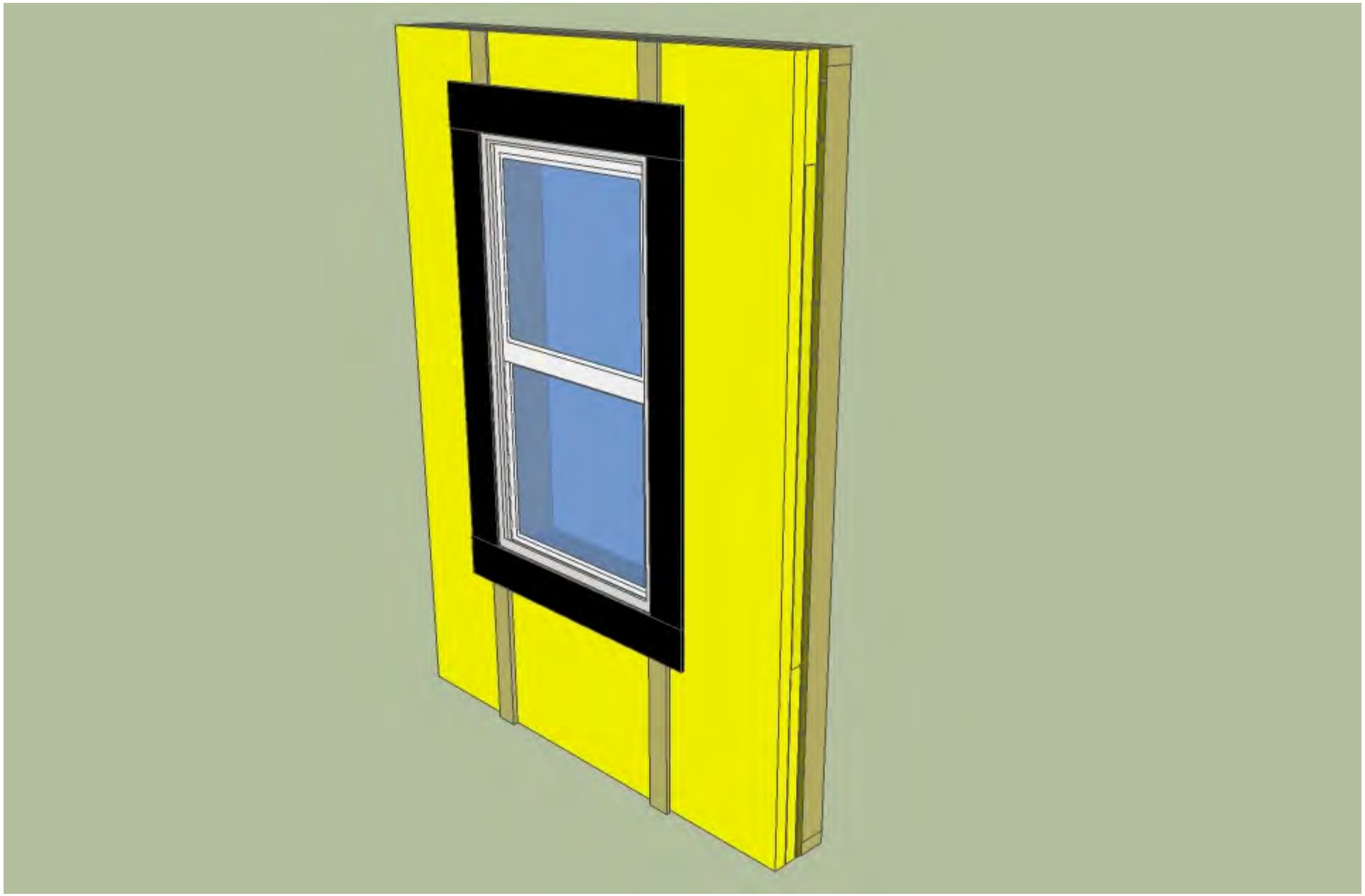
Second layer of insulation installed, seams taped



Rough opening strapped with 1x3 nailers, window installed

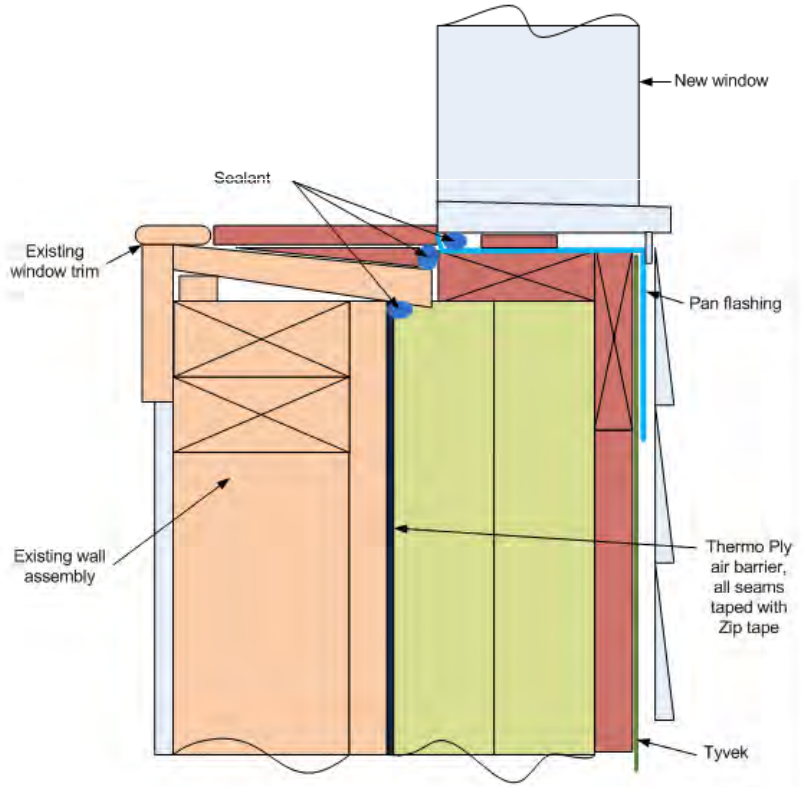


Peel & stick membrane spline flashing installed



1x3 exterior strapping installed in line with studs, ready for siding

DEEP Energy Retrofit
Window replacement using
existing interior trim
Window Sill Detail



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WARNING

07/20/2010

07/13/2010

KALEX ENERGY COMPANY
"SAVING ENERGY ONE HOUSE AT A TIME"
PERMIT
ply

Berry Plastics
Tapes & Coating Div.
Constantine, MI
www.berryplastics.com 800-345-8881
TOUGH PROTECTIVE

CFL

RIPCORD® Split Releas
GRACE Roof Detail Mem

Thermo
ply
TOUGH PROTECTIVE SHEATHING
RED STRUCTURAL GRADE
050110

TUFF-R
Commercial Insulation

THERMA TRU
DOORS

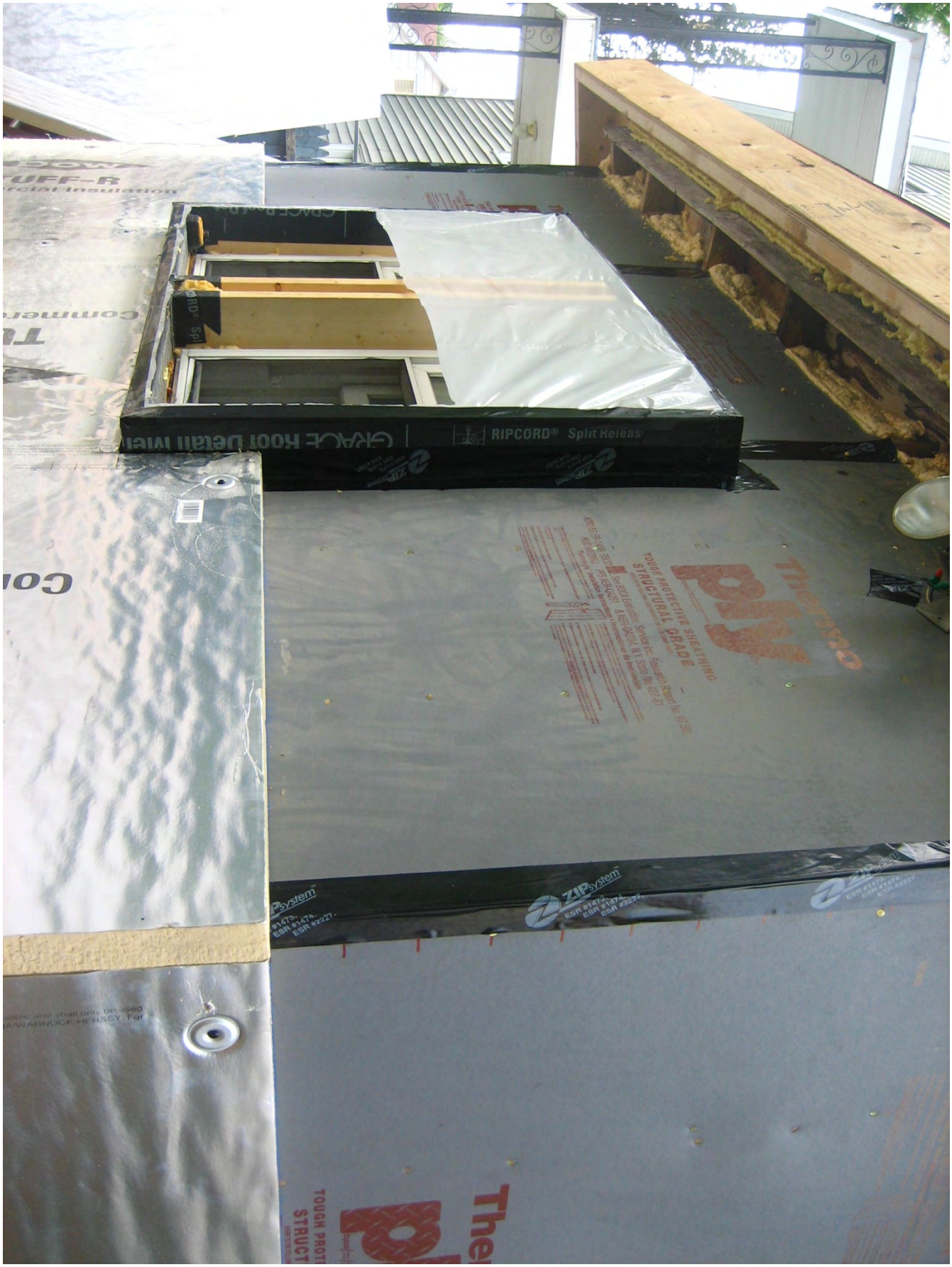
Roof Detail Membrane
RIPCORD® Split Release Underlayment
GRACE Roof Detail Membrane
Thermo
ply

Thermo
ply
TOUGH PROTECTIVE SHEATHING
STRUCTURAL GRADE
GRACE Roof Detail Membrane

07/20/2010

Thermo
ply
Thermo
ply
07/28/2010

DOW
TUFF-R
Commercial Insulation
07/20/2010


RIPCORD®
ZIP System

07/26/2010

07/26/2010

08/03/2010

08/03/2010

08/03/2010

DOW
TUFF-R
Commercial Insulation
TUFF-R
Commercial Insulation
DOW
TUFF-R
CONTRACTORS SHALL
ALL DEBRIS FROM
CITY OF U
BUILDING
THIS CARD MUST
07/20/2010

Porches

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RIPCORD™
Split Release
ply

DOW
TUFF-R
Commercial Insulation
DOW
TUFF-R
Commercial Insulation

11/14/2010

Attic Eve

Thermo
ply
GRACE Root Detail Membrane
GRACE Root Detail M
Thermo
ply
tyco

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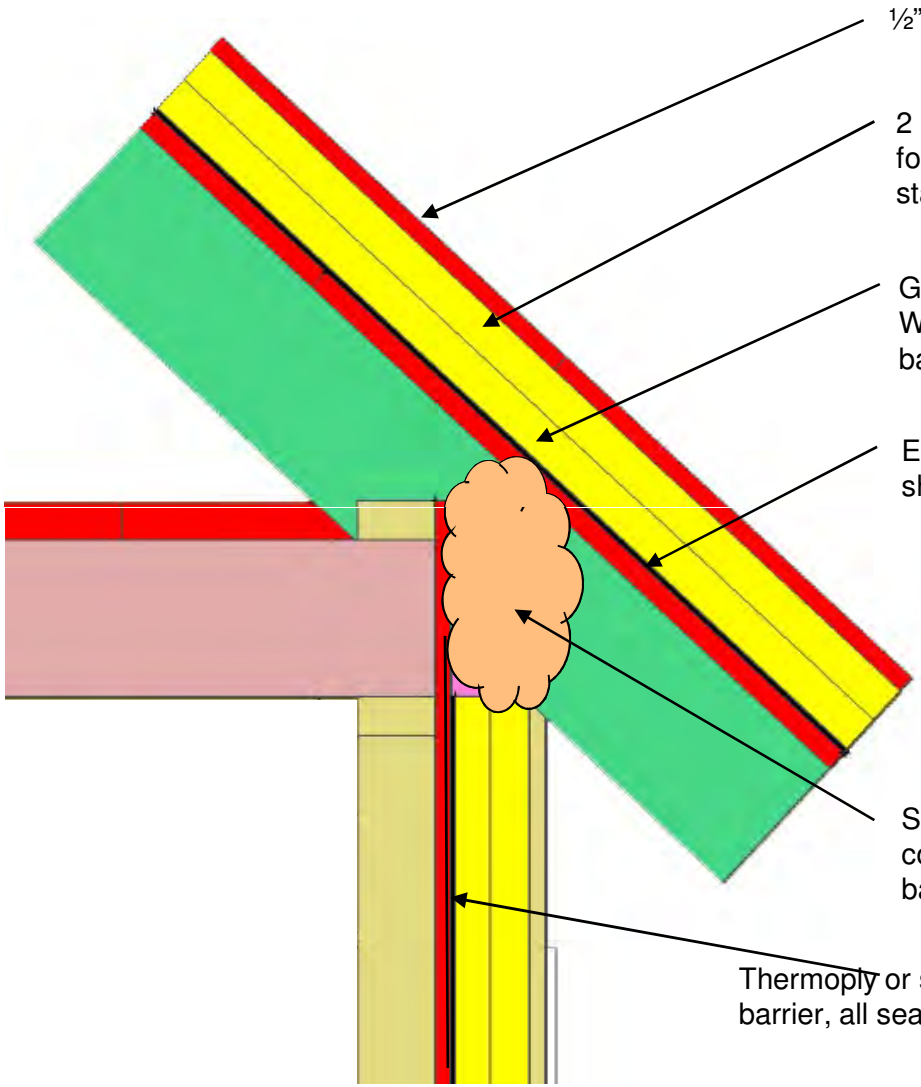
Attics

- There are compelling reasons to define the thermal envelope at the attic floor
- Attics are more approachable
- Keeps crews off the roof
- Weather is less of a problem
- Workmen’s Comp.Insurance considerations

The Roof

- Combine new roof opportunity with improved exterior insulation strategy
- Consider metal roofing, saves on material and labor to install

Exterior wall to eave/roof detail
NYSERDA DEEP Energy Retrofit Pilot- Utica, NY
Prepared by Vermont Energy Investment Corporation
3/28/10



07/05/2010

DuPont
Tyvek
Tape
07/05/2010

-R
Insulation
-R

07/20/2010

Mechanical Systems

- Strategy
- Water/space heating
- Distribution
- Ventilation

Mechanical system must provide:

- Heat
- Hot water
- Controlled mechanical ventilation

Mechanical Strategy

- Re-size heating equipment to match new load
- Combine heating and water heating appliance, if possible
- Ventilation with a heat recovery ventilator
- Distribute heat and ventilation air with high efficiency fan coil and existing ductwork.

Heat and DHW options:

- Tank less water heater only (82%)
- Tank less water heater plumbed to small storage tank with circulator (75-80%)
- High efficiency storage tank-type heater (95%)

High efficiency water heaters

Instantaneous Tankless
DHW and
Space Heating
99 kBTU/hr

> 80% efficiency

Relatively low cost (for high efficiency appliance)

Spark Ignition (no pilot)

High efficiency water heaters

Condensing Tank type
DHW and
Space Heating
100 – 199 kBTU/hr

55-119 gallons

97% efficiency

Spark Ignition
Version with solar heat exchanger also.

Combi Tank less system installed

Fan Coils

Makes hot air for distribution with hot water from the water heater.

Takes place of the old furnace

Fan Coils

- A fan coil replaces a forced air furnace - both make warm air
- A fan coil uses a source of hot water in a finned copper coil to make warm air
- Fan coils are available in many sizes and configurations, which make it easier to size a heating system properly for a low load building
- The best modern fan coils use variable speed motors to save energy, soft start, and provide low speed air circulation
- Water heaters are an excellent source of hot water for fan coils
- This strategy uses only one combustion source per house
- The high efficiency water heater is sidewall vented, so the chimney can be demolished to below the thermal boundary
- A two unit house can use a single high output, high efficiency water heater that provides hot water to two fan coils, one per unit - saves money but loses separate tenant gas billing

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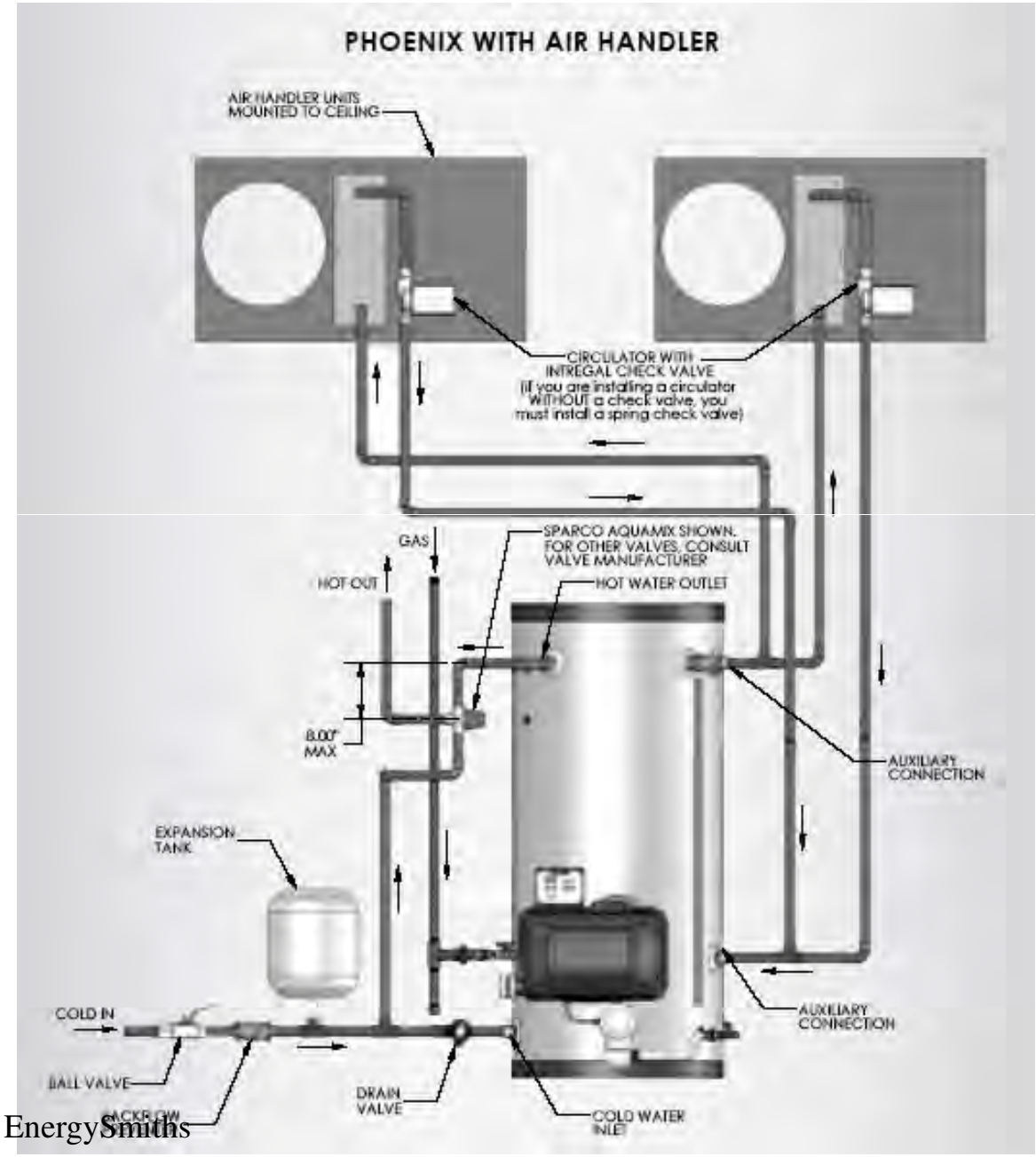
Heating with a Fan Coil



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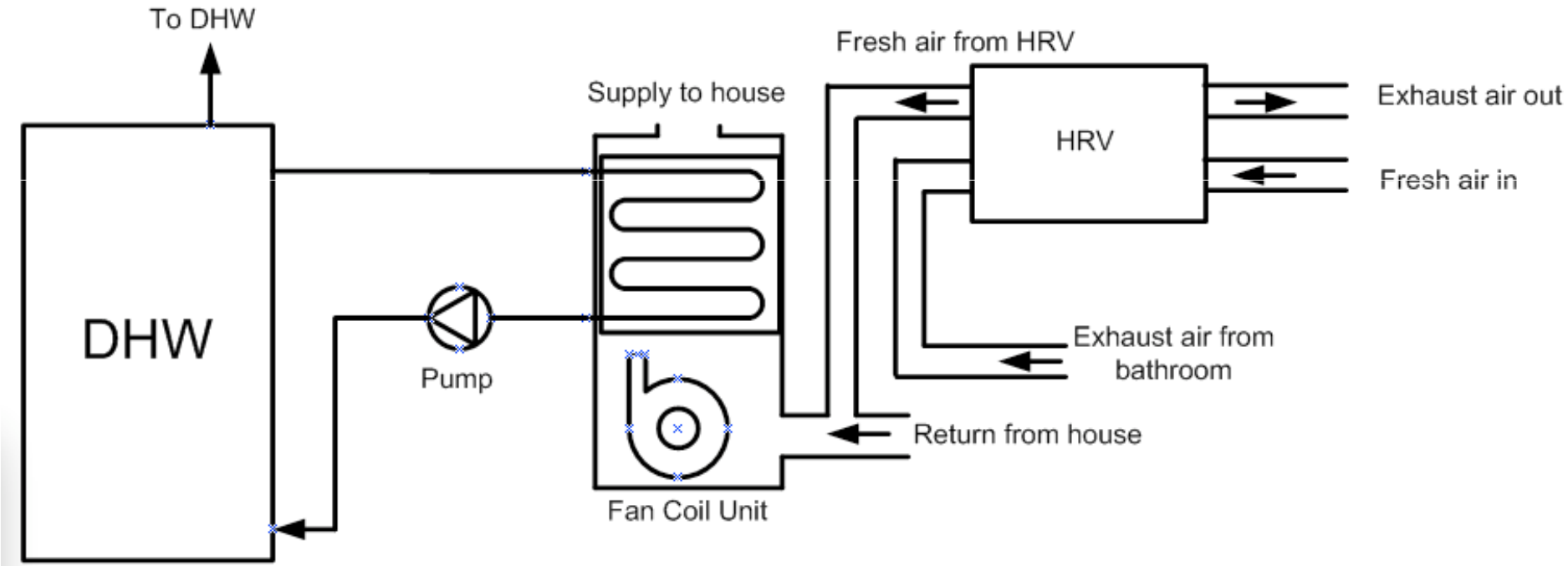
Rinnai
HYDRONIC FURNACE
Rinnai

HRV integrated with Fan Coil



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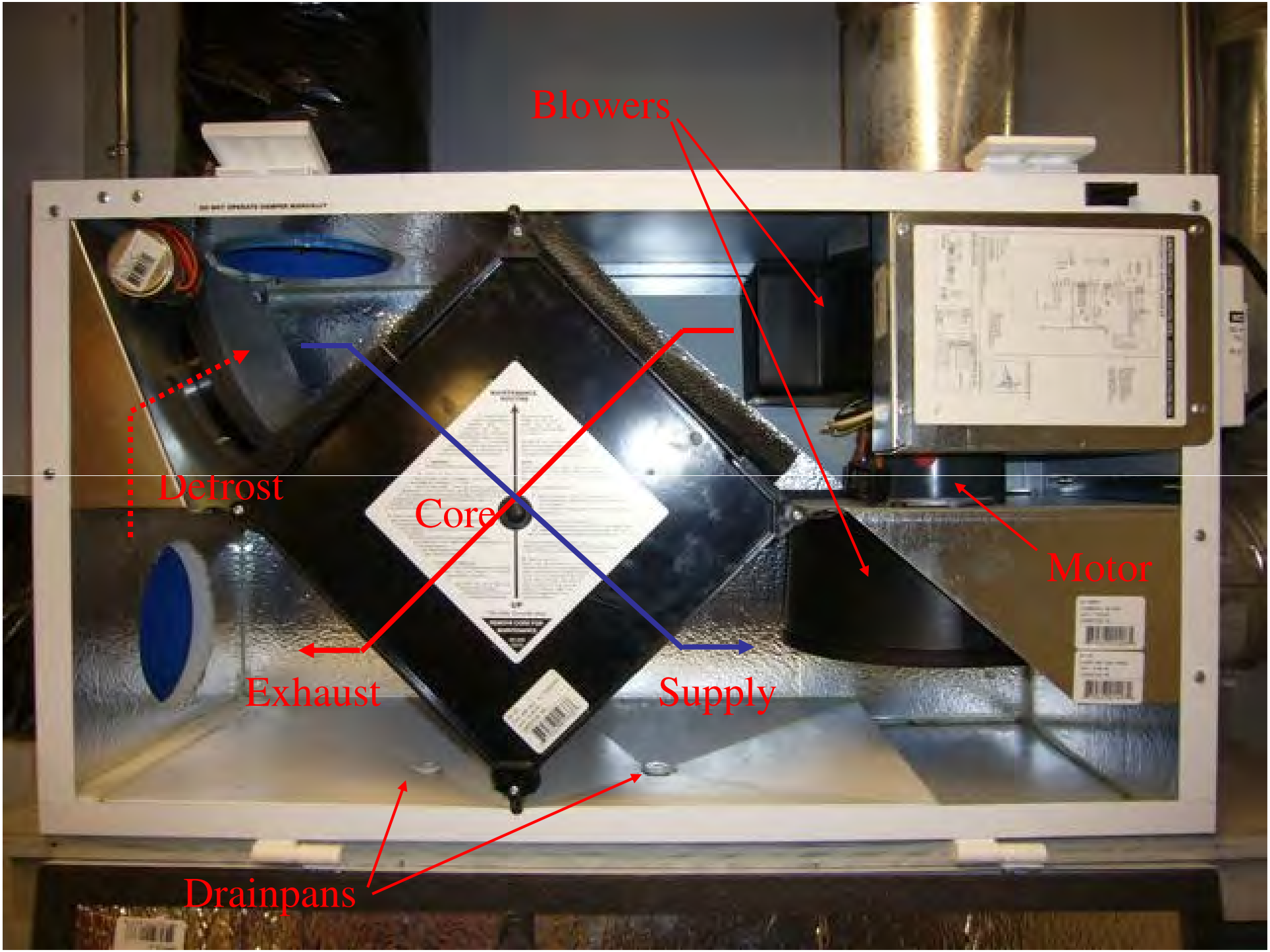
Nu-Air Hydronic Furnace fan coil unit with integrated HRV

Heat Recovery Ventilators

Provide fresh ventilation air

Recover heat from exhaust stream to preheat the supply stream

Installed to use existing ductwork


Blowers
Defrost
Core
Motor
Exhaust
Supply
Drainpans

Descaling

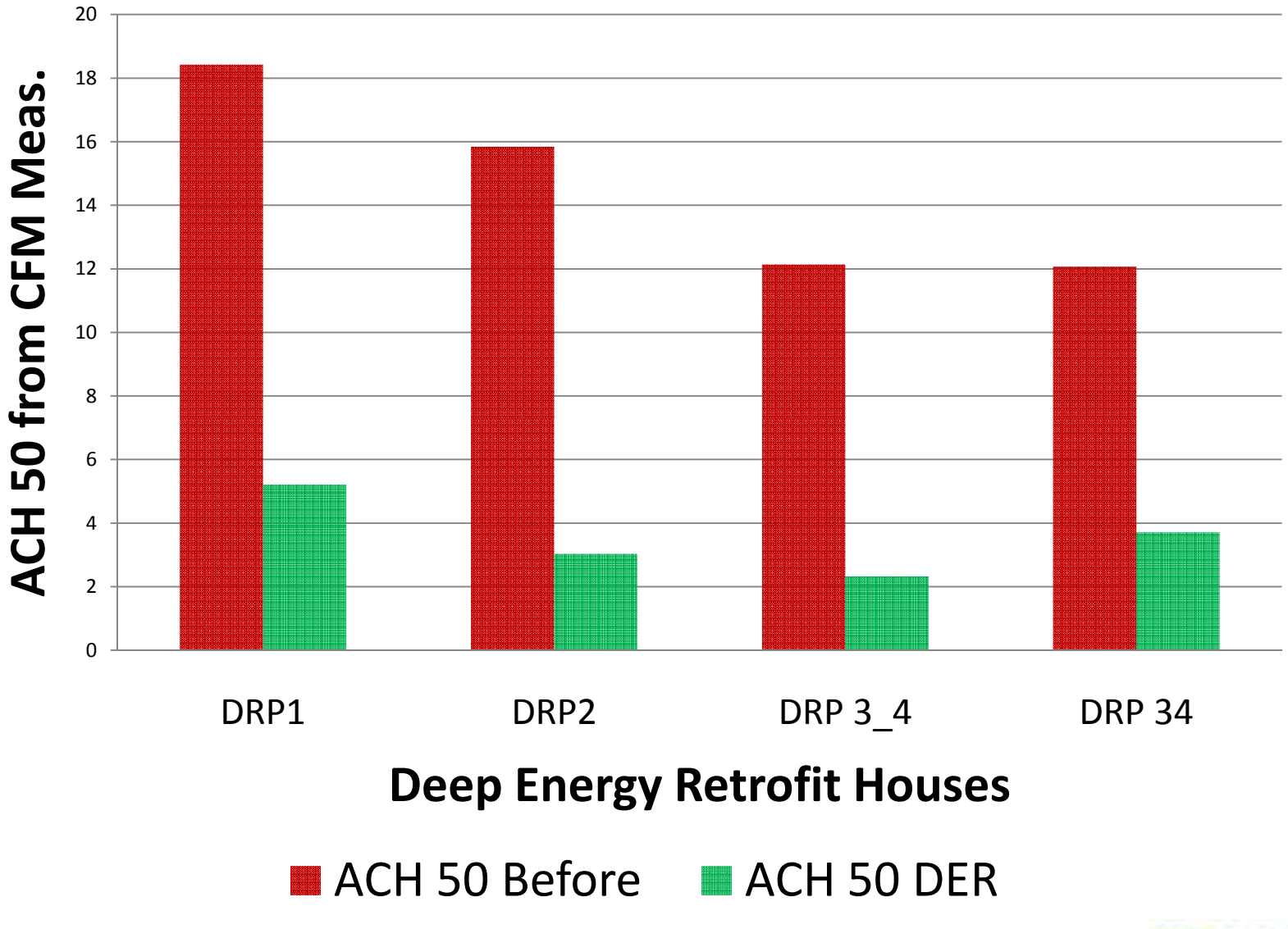
- High temps causing calcification
- Descaling-
- Different water hardnesses can cause different problems, as can the solutions.
- Tankless water heater maintenance: http://www.youtube.com/watch?v=nQYyoe0GFag

Using Existing Ductwork

- The existing ductwork in the two homes we saw is undersized for the air flow rate of the furnace (~1,000 CFM)
- With a three-fold reduction in load, the air flow required will drop - although the fan coil will deliver less hot air than a furnace (~120F vs. ~135F)
- All ductwork seams must be sealed
- Asbestos must be encapsulated
- Ductwork should be insulated
- Ductwork may need to be cleaned
- Optimally, ductwork reaches every bedroom so fresh air is delivered - where this doesn't happen, fresh air should be ducted separately

Results from DER Pilot

Change in Air Flow



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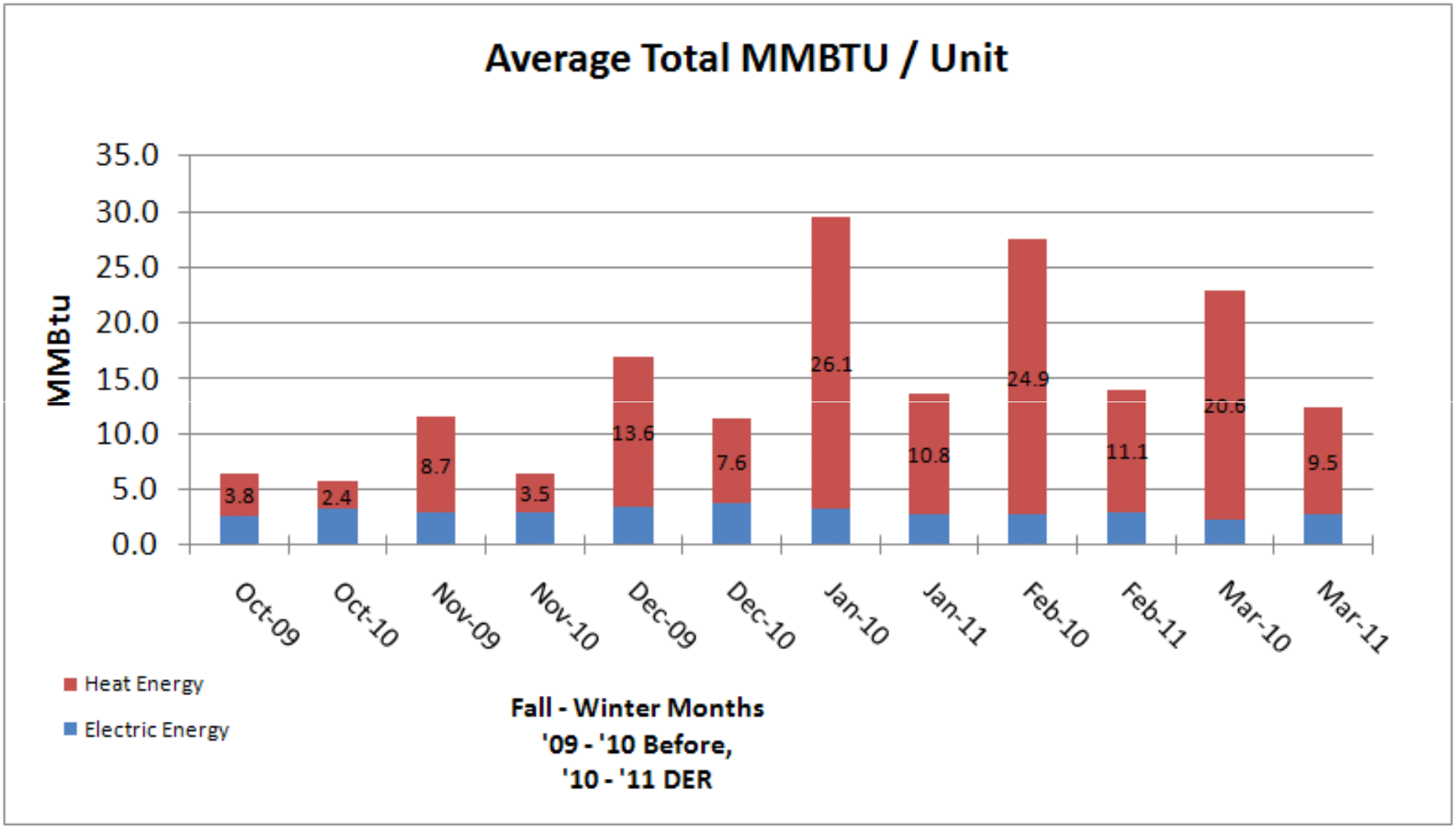
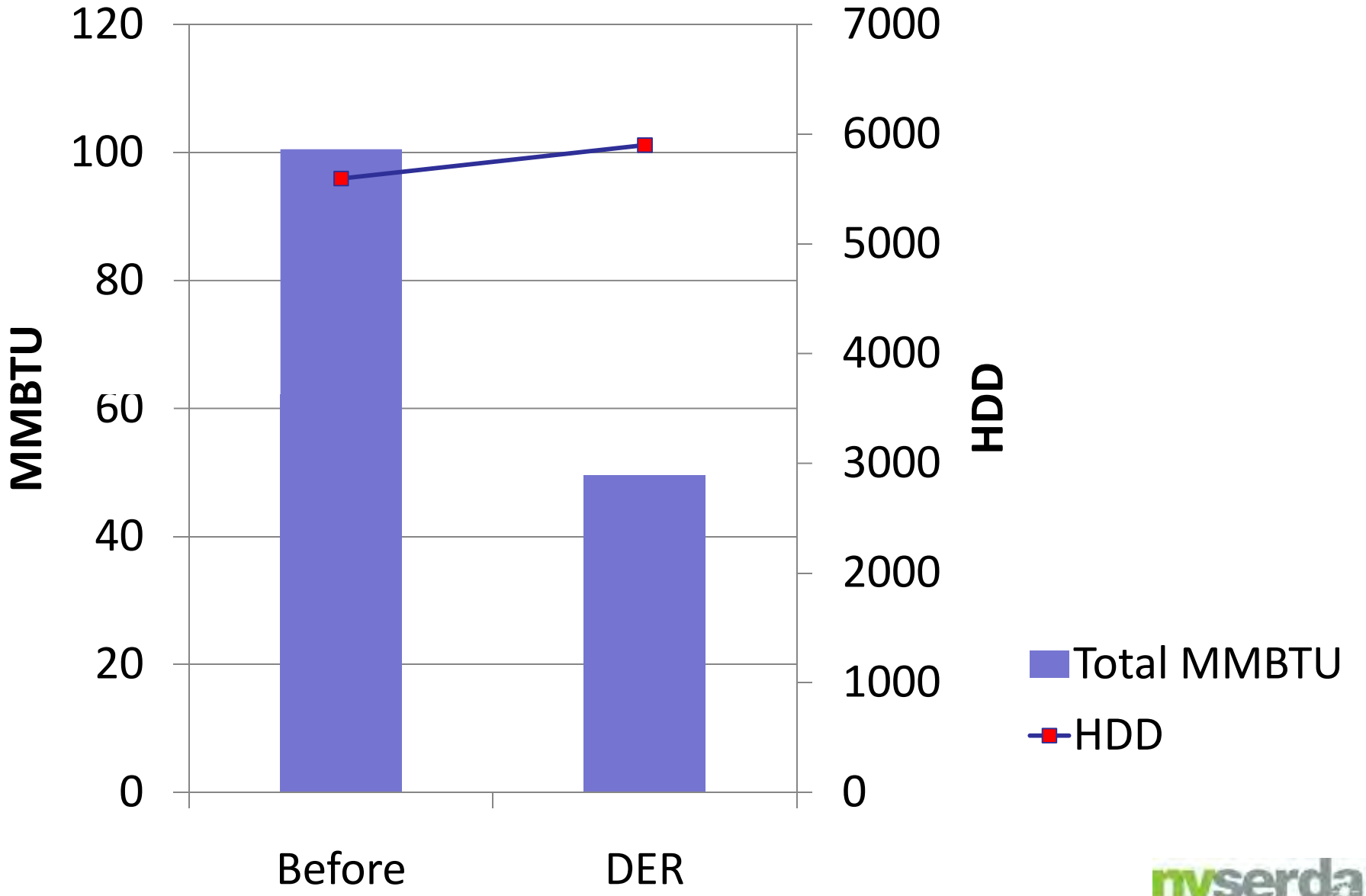

Average Total MMBTU / Unit
MMBtu
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
3.8
2.4
8.7
3.5
13.6
7.6
26.1
10.8
24.9
11.1
20.6
9.5
Oct-09
Oct-10
Nov-09
Nov-10
Dec-09
Dec-10
Jan-10
Jan-11
Feb-10
Feb-11
Mar-10
Mar-11
Heat Energy
Electric Energy
Fall - Winter Months
'09 - '10 Before,
'10 - '11 DER

MMBTU/unit and Total Heating Degree Days



Four (4) Completed Deep Retrofit Sites …

	DRP 1	DRP 2	DRP 3_4	DRP 34
Age of Home (yrs.)	100	100	100	100
Finished Floor Area (sq ft)	960	1,118	2,754	1,534
Total Occupants	2	4	7	6
CFM 50 before / DER (ssf)	1.22 / 0.35	1.16 / 0.22	0.92 / 0.18	0.63 / 0.28
ACH 50 before / DER	18.4 / 5.2 (72 % reduction)	15.8 / 3.0 (81 % reduction)	12.1 / 2.3 (81 % reduction)	12.0 / 3.7 (69 % reduction)
Below Grade Wall (BGW)	$14,833	$13,767	$15,985	$20,199
Above Grade Wall (AGW), windows and doors	$29,588	$44,676	$66,070	$54,387
Roof / Attic	$17,460	$11,414	$23,693	$6,192
Mechanicals	$13,401	$11,497	$13,036	$11,041
Deferred Maintenance Issues	$22,917	$14,865	$25,217	$18,681
Total Project Cost	$98,199	$96,219	$144,001	$110,500
Less deferred maint /unit cost	**$75,282**	**$81,354**	**$59,392**	**$91,819**

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