# Practical Strategies for Heating Dominated Climates:

## High Performance, Low Energy
## DETAILS IN THE FIELD

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Rachel Wagner
www.wagnerzaun.com

Wagner Zaun Architecture
17 N Lake Avenue
Duluth, MN 55802

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Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

# Learning Objectives – Part 1

**1. Introduction: Defining High performance/low energy**
An integrated approach

**2. One Size Does Not Fit All: The Use of Design**
How building design impacts performance and energy use
Determining how much, when, and where

**3. Water Management**
The key to durability - everywhere

**4. Air Sealing**
Managing heat, air and moisture - everywhere

**5. A Good Foundation**
Basement/foundation walls
Insulated Slab on grade

# Learning Objectives – Part 2

6. **Framed Walls**
   Double stud
   Single stud with foam sheathing

7. **Windows**
   Product and performance
   Installation details

8. **The Roof**
   What it should always do and can do
   Details for attics and for vaulted ceilings

9. **Systems (Mechanical, Electrical, Plumbing):**
   Guidelines for low energy, high performance
   Matching performance to intent

10. **Results of an Integrated Approach**

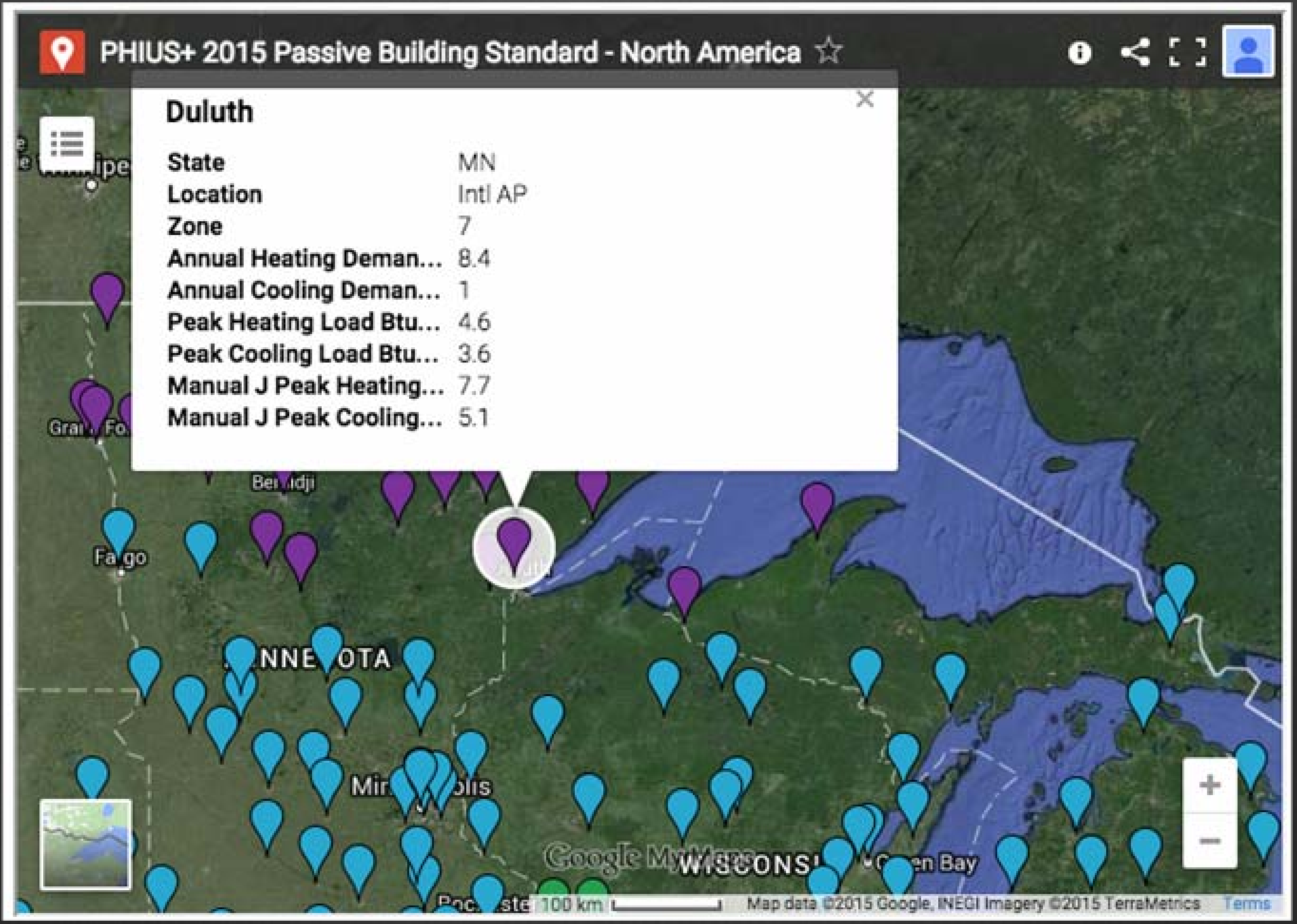
# Defining High Performance, Low Energy

# Designing to Energy Targets:

## We use a baseline of code and compare versions of the same house

| Modeled Energy Data - "House X" | | Code | Design |
|---|---|---|---|
| Peak Heating Load | | | |
| | Btu/hr | 64,500 Btu/hr | 23,700 Btu/hr |
| | | | |
| | Btu/hr/ft2 | 11.35 Btu/hr/ft2 | 4.53 Btu/hr/ft2 |
| | | | |
| Annual Heating Demand | | Code | Design |
| | MMBtu/year | 106.5 MMBtu/yr | 24.1MMBtu/yr |
| | | | |
| | kBtu/ft2 annual | 18.75 kBtu/ft2/yr | 4.61 kBtu/ft2/yr |

# PHIUS+ Target Duluth, MN



# High Performance is About More than Energy

- FUNCTIONALITY – make it understandable, easy to use
- DURABILITY – make it last and easy to maintain
- ADAPTABILITY – be able to change it
- COMFORT – make it feel good
- HEALTH – minimize the risks to occupants
- RESILIENCY – make it work under a variety of conditions

# Seeing the Forest for the Trees

"When we try to pick out anything by itself, we find it hitched to everything else in the Universe."

- John Muir (1838-1914), engineer, naturalist

# The Priorities

1. Healthy for Occupants.
2. Durable.
3. Requires less energy. A lot less.

# Designing for High Performance, Low Energy

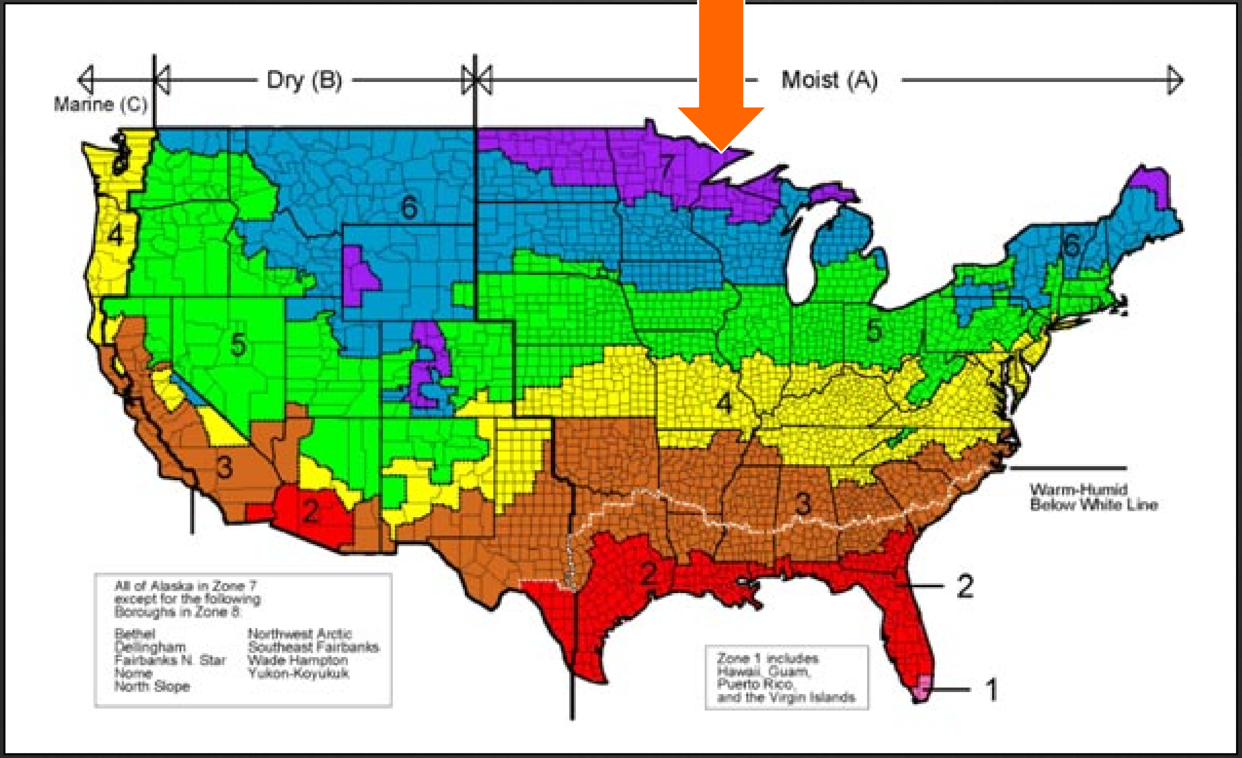
1. Understand how form, assemblies, and materials affect energy and durability.
2. Create a building form that helps manage water, heat, and air flow.
3. Maximize use of the sun.
4. Provide occupant comfort under a variety of conditions.
5. Include systems of Energy Flexibility.
6. Minimize vulnerability to the occupants.

# Region plays a role.

In 2009, the average Wisconsin household uses 103 million Btu of energy per home, 15% more than the U.S. average.

Source EIA

Where I live and work



# *Designing* a High Performance, Low Energy Home
# in a COLD CLIMATE

What's different?

# Cold Climate Matters

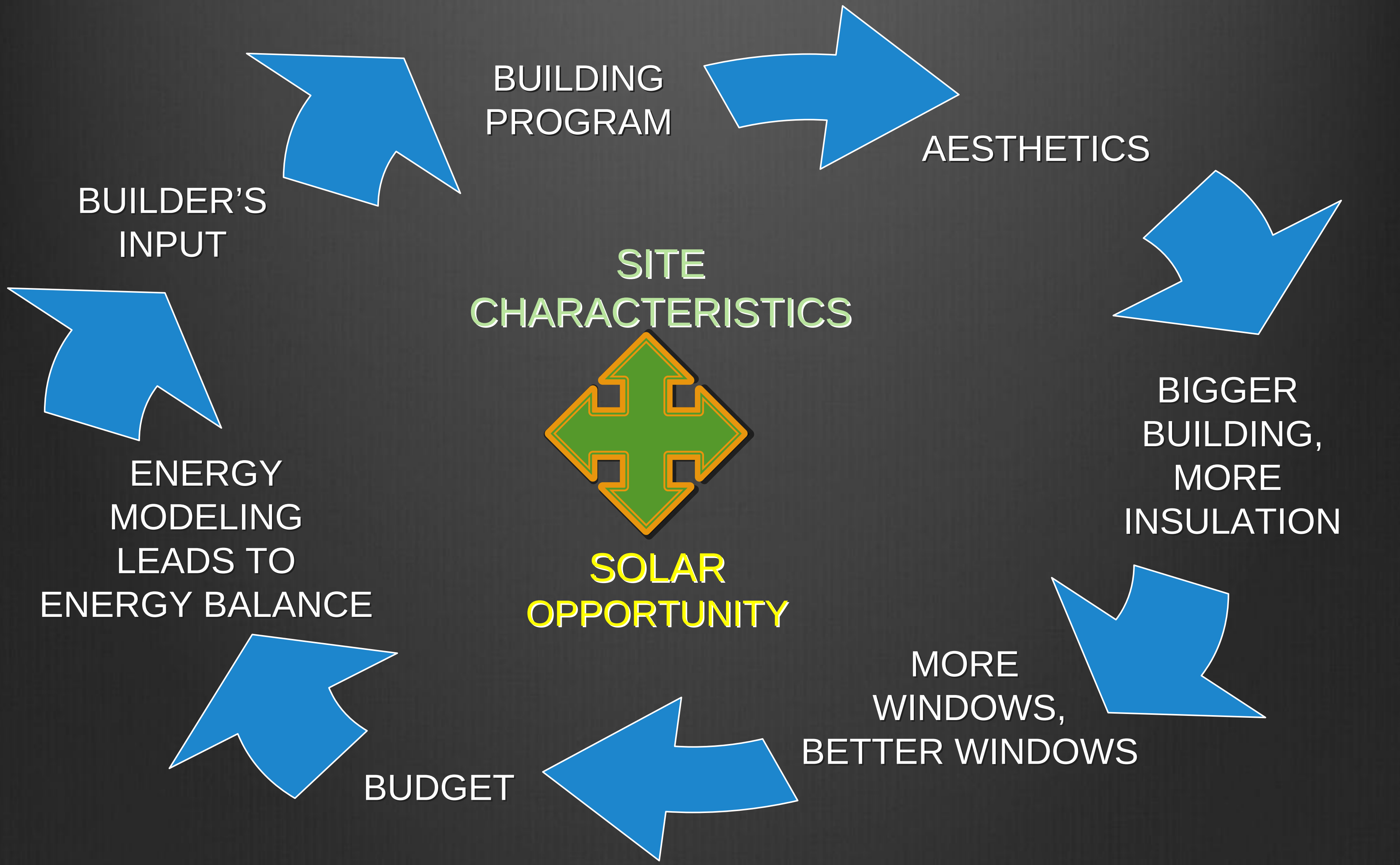
1. Heating season, peak load, and demand
2. Little or no cooling load
3. The sun – a commodity
4. Construction during winters
5. Vapor retarders – if, when and how
6. Mechanical Systems Limitations
7. Snow and Wind

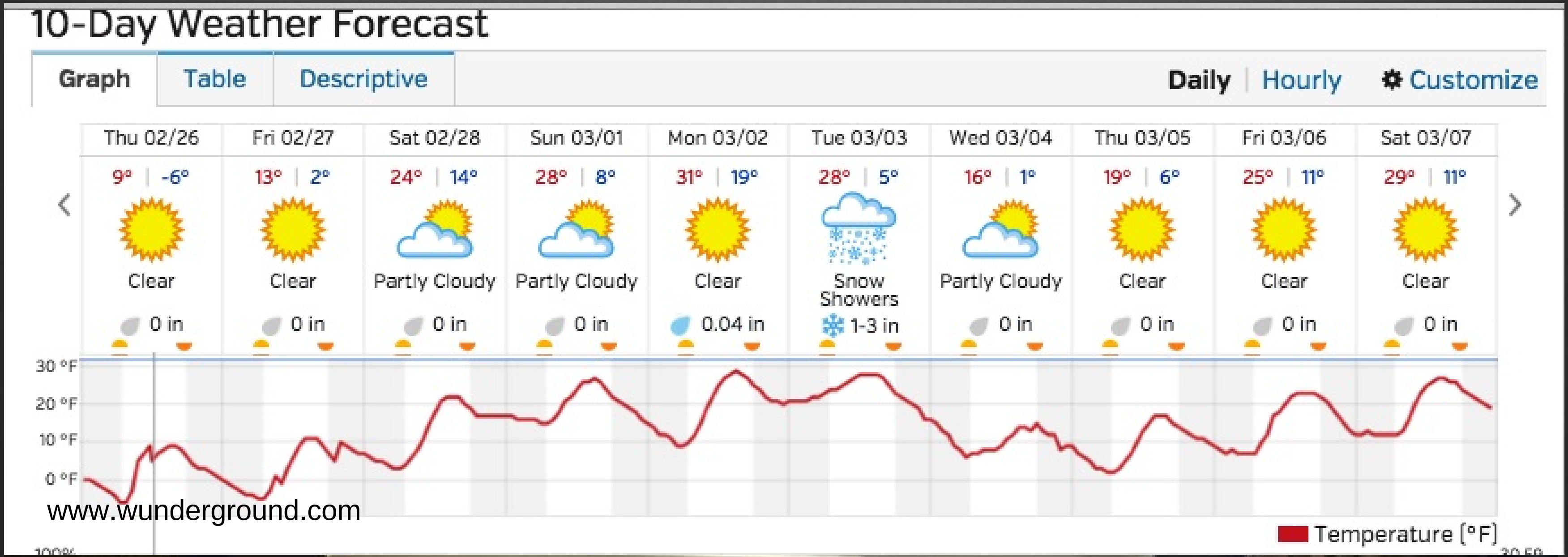
# One Size Does Not Fit All

- Big house or small house?
- Simple building form or complex form?
- Construction costs vs operating costs
- Orientation and solar opportunity
- Site constraints and topography
- Regional preferences and materials

All will affect choices made to achieve high performance and low energy.

# Integrating how much, where, and how





10-Day Weather Forecast
Graph
Table
Descriptive
Daily
Hourly
Customize
Thu 02/26 9° | -6° Clear 0 in
Fri 02/27 13° | 2° Clear 0 in
Sat 02/28 24° | 14° Partly Cloudy 0 in
Sun 03/01 28° | 8° Partly Cloudy 0 in
Mon 03/02 31° | 19° Clear 0.04 in
Tue 03/03 28° | 5° Snow Showers 1-3 in
Wed 03/04 16° | 1° Partly Cloudy 0 in
Thu 03/05 19° | 6° Clear 0 in
Fri 03/06 25° | 11° Clear 0 in
Sat 03/07 29° | 11° Clear 0 in
30 °F
20 °F
10 °F
0 °F
www.wunderground.com
Temperature (°F)


# Enclosure + Sun + Systems

If there is no solar gain, even a highly insulated house will gradually cool off. The more insulation, the slower the temperature in the house will drop, but drop it will. With a reasonable amount of passive solar gain and a really well-insulated building envelope, enough heat will enter the house to compensate for most of that heat loss in all but the cloudiest weather.

Alex Wilson, Building Green, 2012

# Area of South-facing Windows

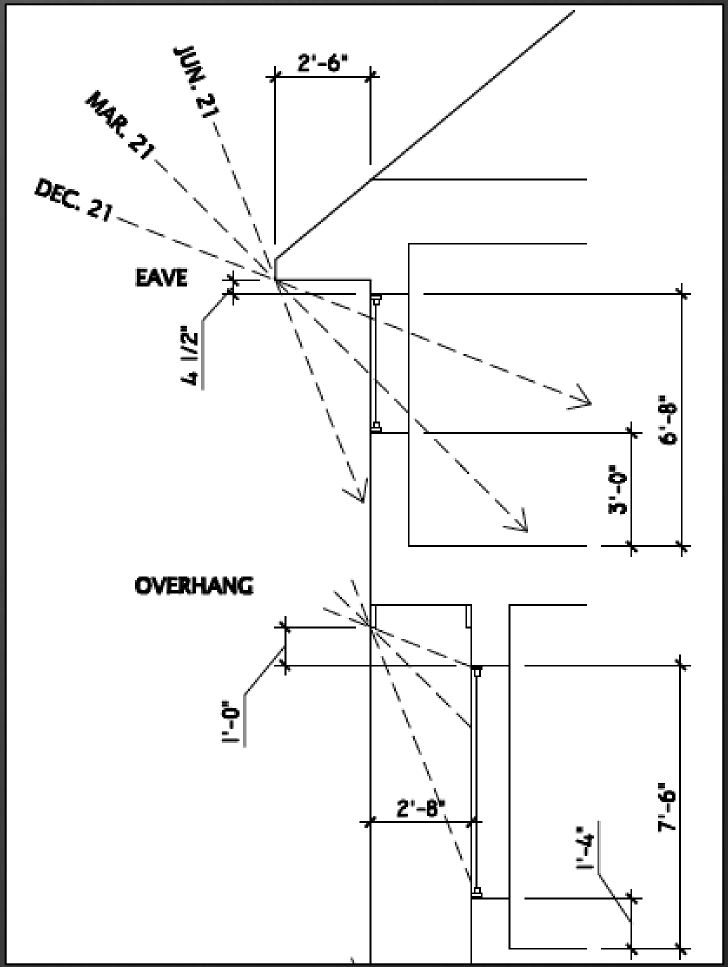
- Calculated south facing glass: 8-12% of floor area (usually)
- If sunlight will strike an area of thermal mass, window area can be larger, but this requires careful design to maintain comfort and energy balance.

# Solar-designed overhangs

It's not rocket science
… but it is science.

Properly shade south windows to admit lower altitude of winter sun but block the higher angle of summer sun

- Roof Overhangs
- Trellises
- Sun-shades



# From design to build:
# Real Details in the Field



# Water Management

Water is the source of most building material or assembly failures.

PAY ATTENTION!

- The Site
- Roofs
- Windows and Doors
- Penetrations to the enclosure
- Joints and seams
- The building perimeter

Quiz: Identify at least 5 instances of excellent water management in this photo.

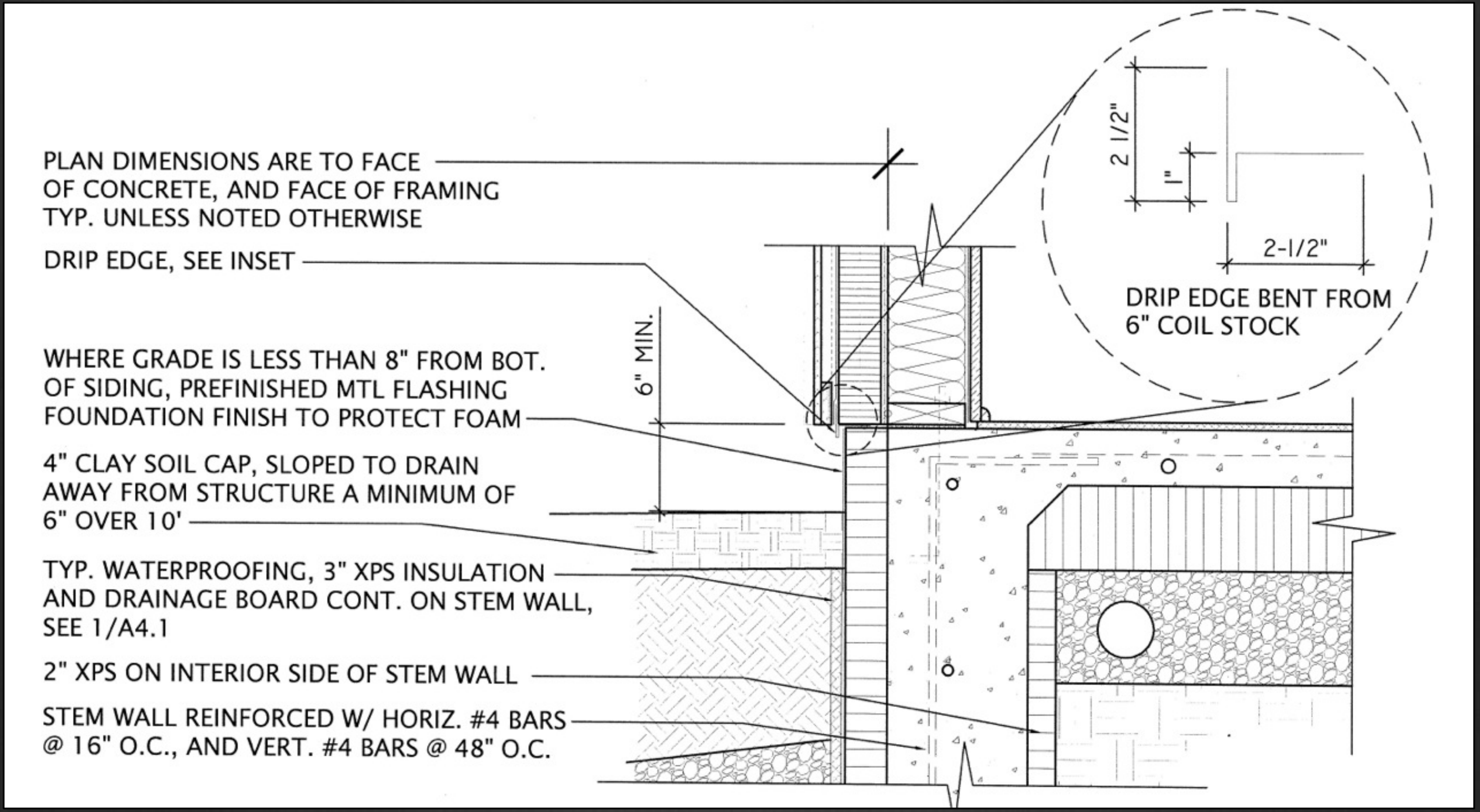
# Design can hamper or enhance durability

Image from ecocor.us

- Assume water will get in.
- Design how it will get out.
- Make your job easier.
- Low energy is useless if the building fails prematurely.
- This image:
  - No roof overhangs
  - Snow collection sills
  - Snow against wood siding

# Good Water Management

# Draw what needs to be done




Understand materials and fastening requirements: don’t draw “magical” details.
(Note: this detail is slab on grade with frost footings on a sloped site.)

# Roofs should shed water (and snow) off the building

and preferably out of the path of pedestrian travel.

Flashing details must keep water out of the structure.

# Water management protects the structure

Manage penetrations

# Why I like rain screens

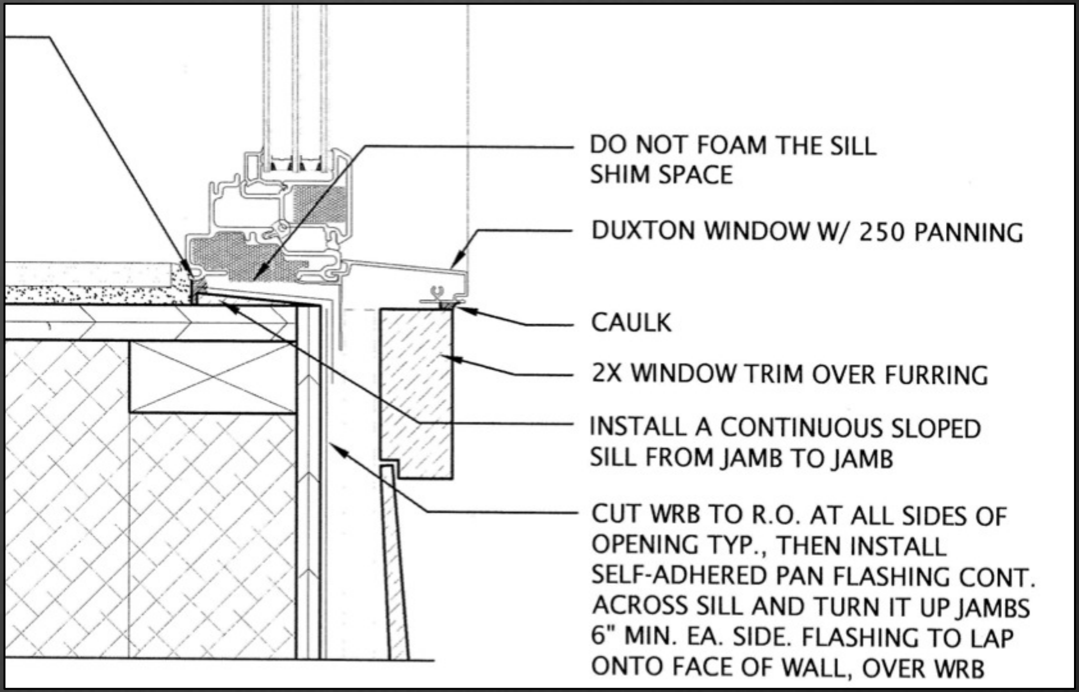

Water has an easy path down the drainage plane.

Cladding and/or sheathing have the ability to dry outward.

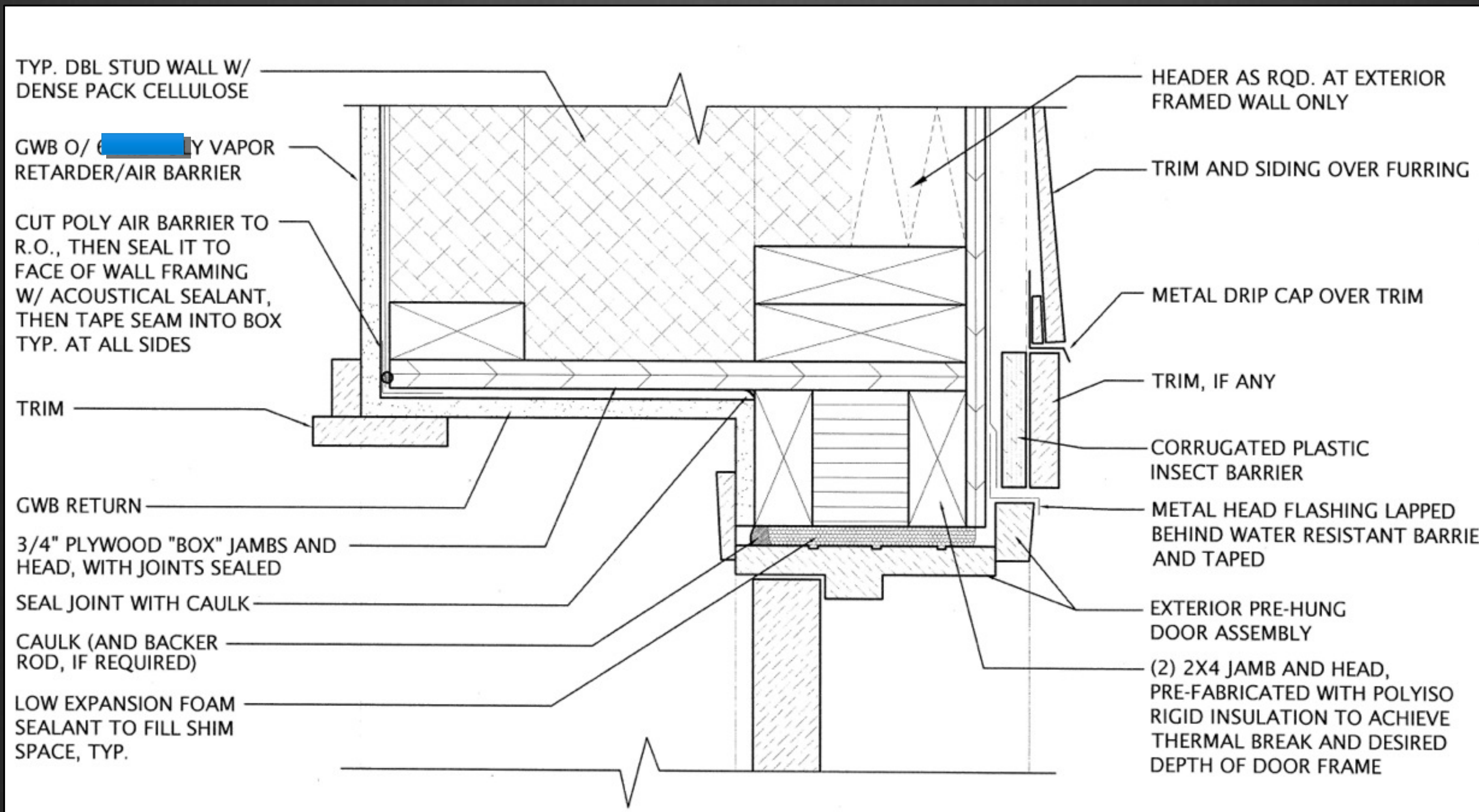
Siding and siding finish last longer.

# Details that matter

- Matrix or furring?
- Window location
- Sill flashing
- Siding material
- Insect barriers
- Draw the openings
- Draw the transitions



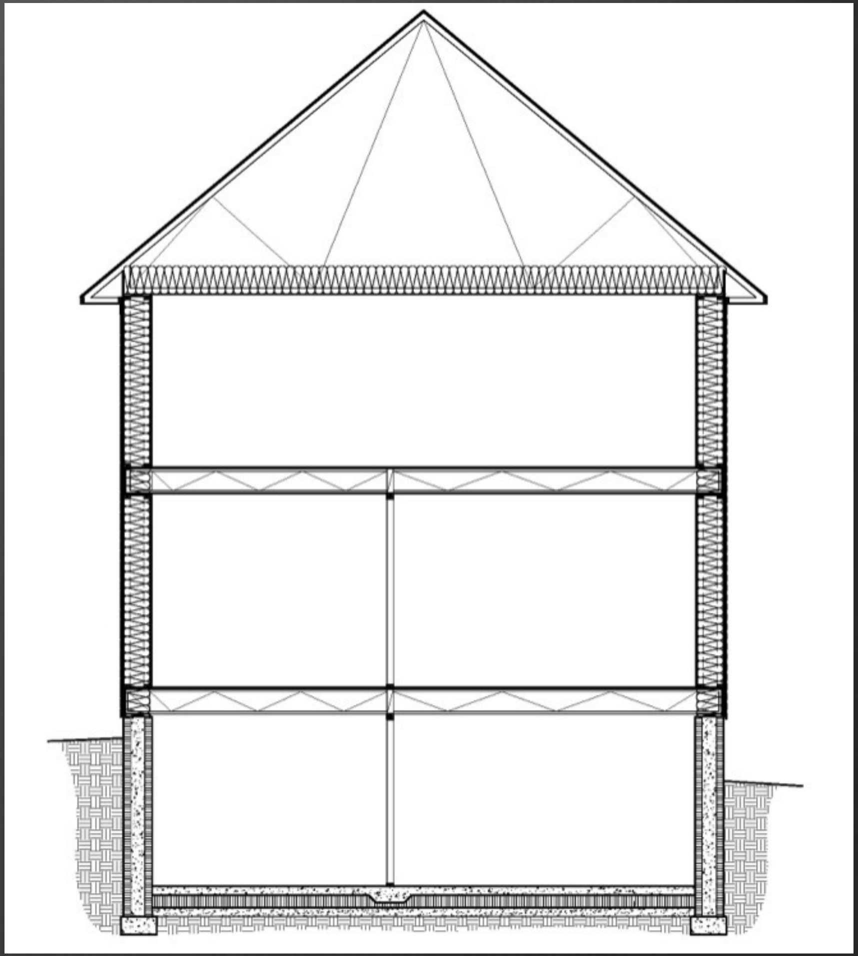
# Managing water, vapor, and bugs



# Managing Air

The air barrier is a continuous assembly of components connected to the entire thermal envelope.

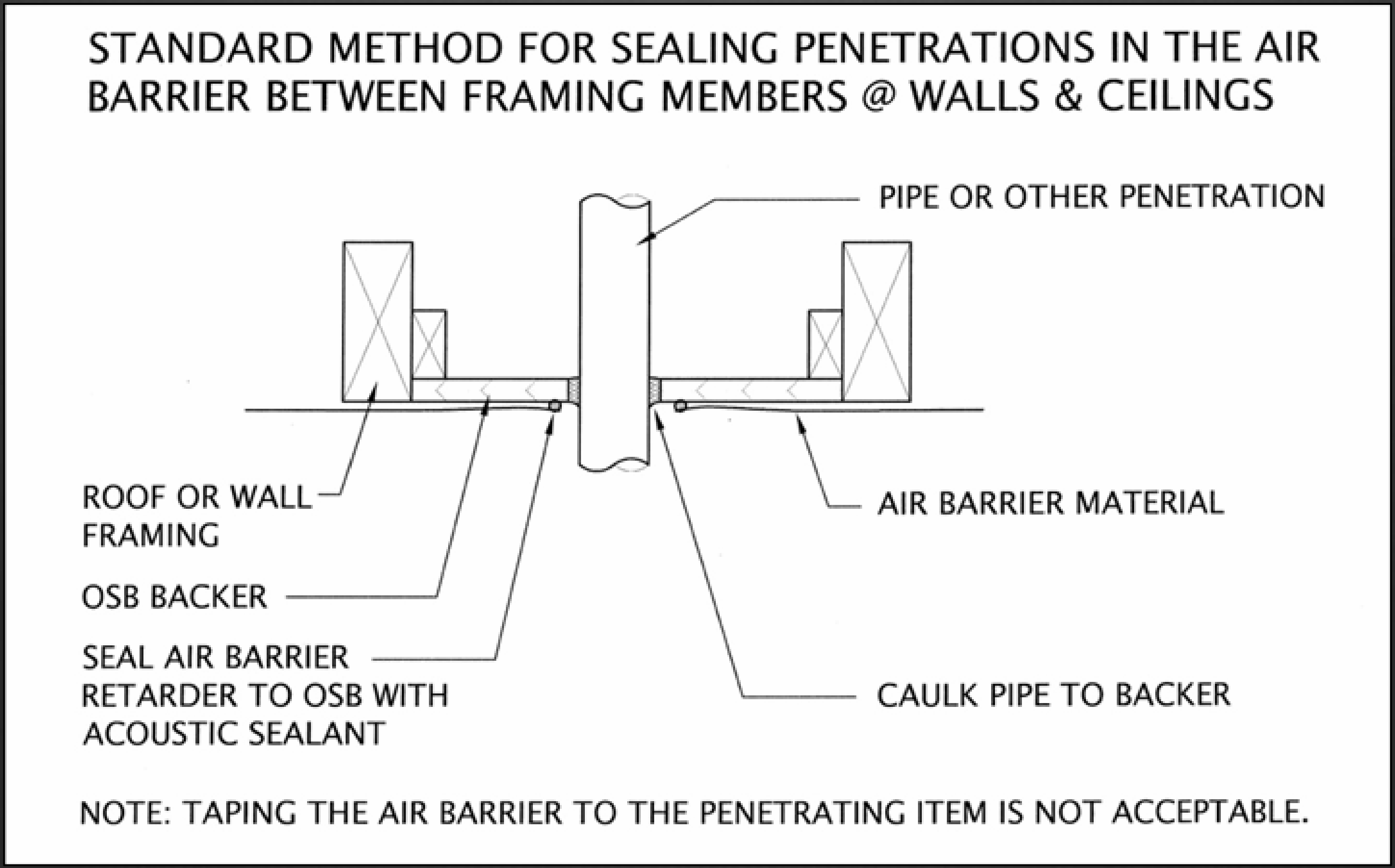
To maintain continuity of the air barrier, the separate components of the assembly must be continuously connected to one another.



# Uncontrolled air leakage poses risks beyond lost energy.

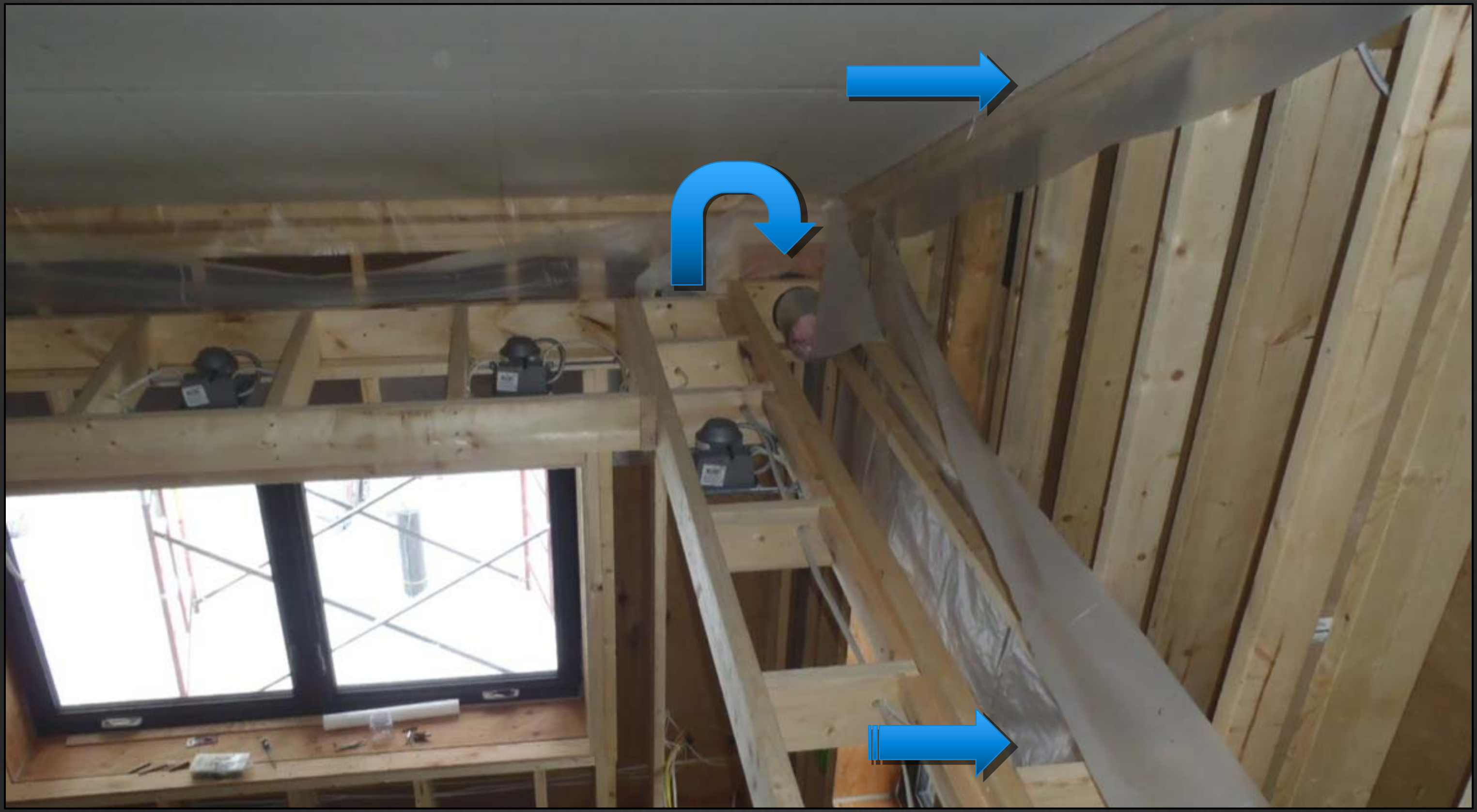
It can create paths and trapped areas for pollutants, moisture, critters and more, causing building damage and unhealthy environments.

# Integrating air barrier language in drawings and specs



# Drawn, specified, built

# Air Sealing:
# doing it right takes time and attention

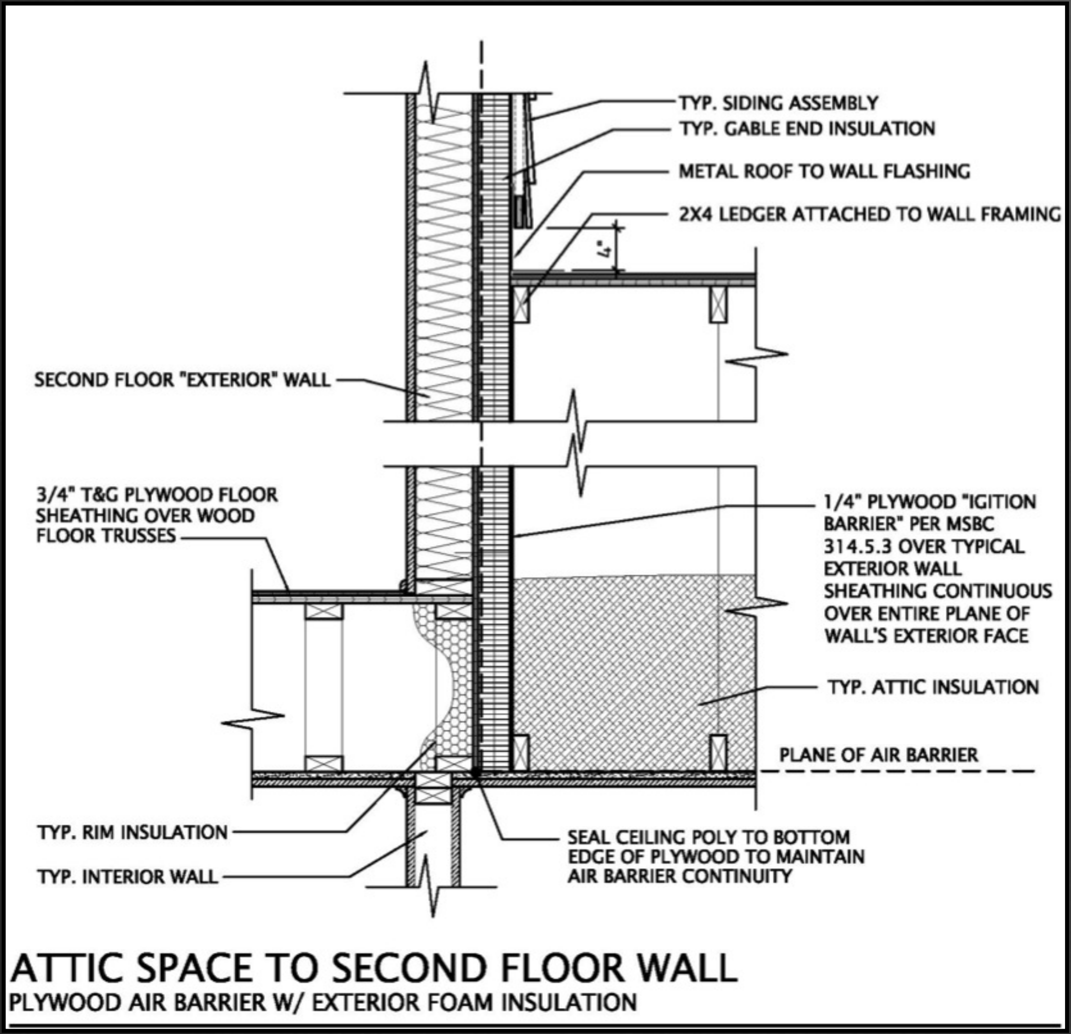


Bad air sealing can make a good envelope perform poorly.

# Airtight window installation

Foam, sealant and backer rod all attach to something solid.

# Continuity can get complicated




Drawing the details at transitions makes a difference.

# Results: Air Tightness in the Field

0.7 ACH50

0.4 ACH50

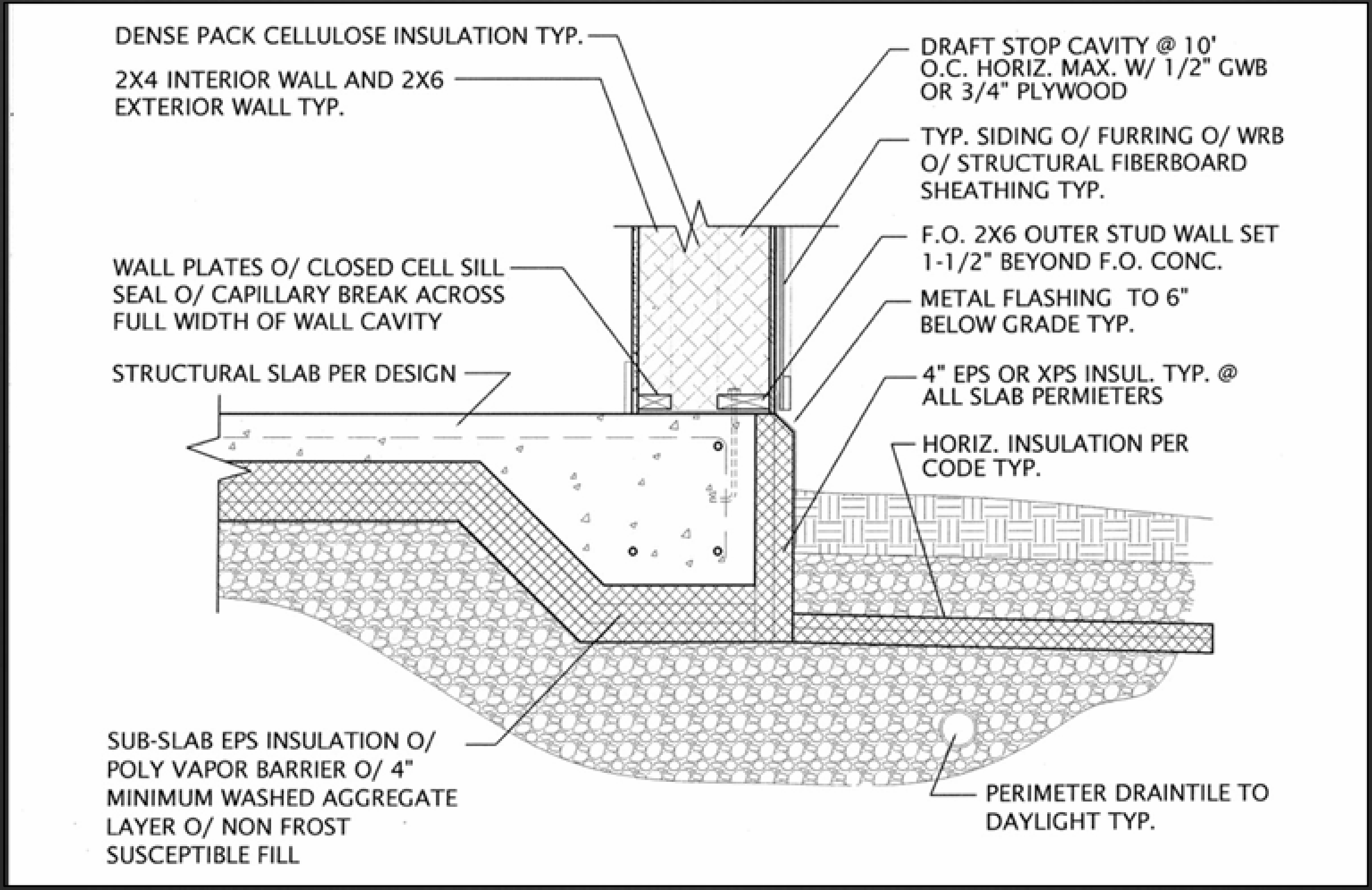
0.5 ACH50


0.26 ACH50

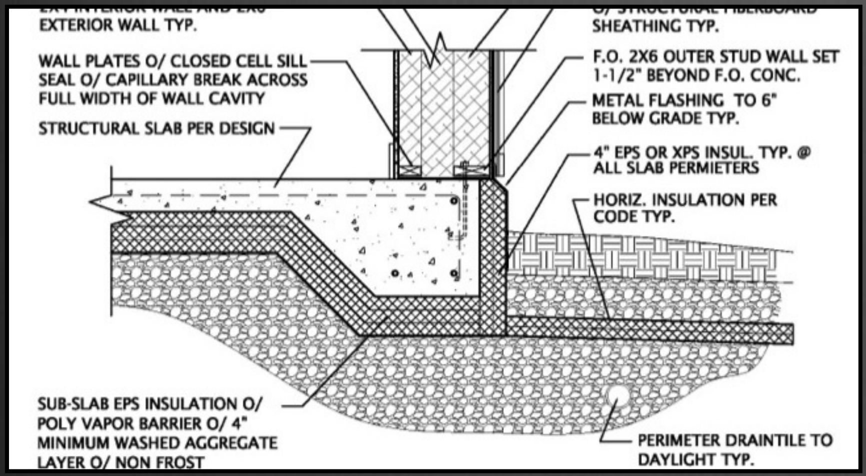
# A Good Foundation

# Frost-protected Monolithic Slab

# Frost Protected Monolithic Slab with Double Stud Wall



# Edge details matter




Can framing overhang the foam?

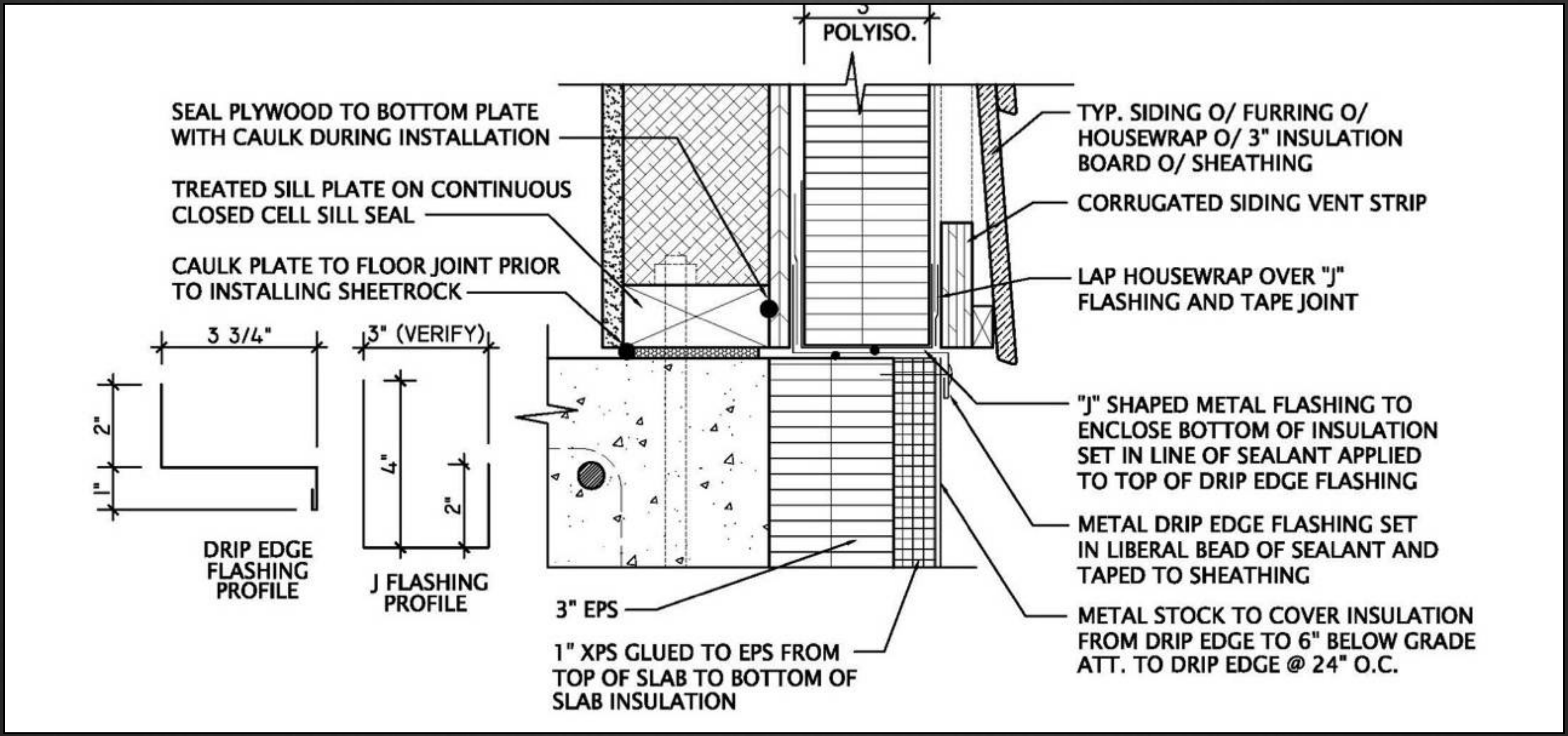
It depends:

Where you are

How much it overhangs

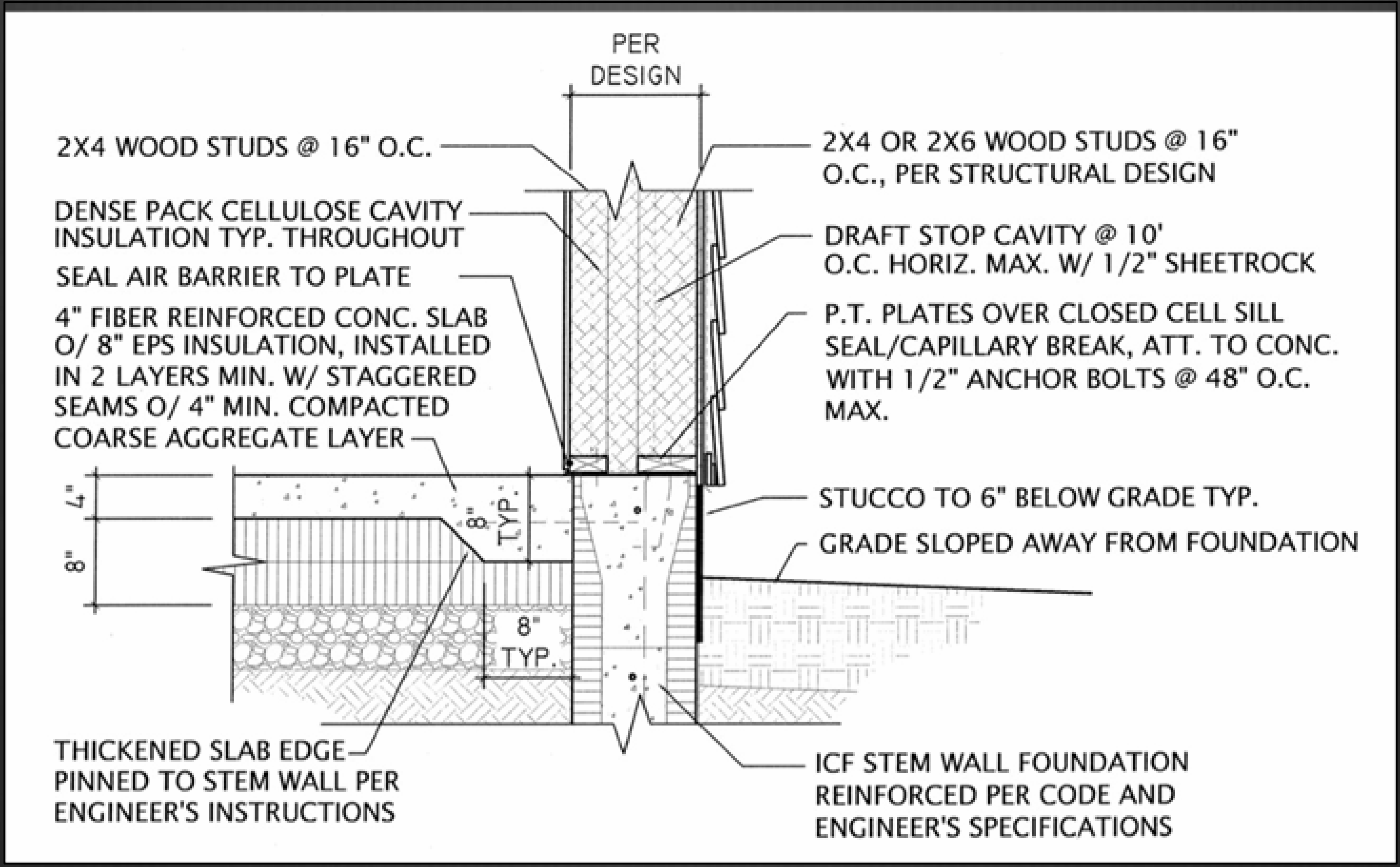
Whether an engineer signed off on it

# Details to manage air and water




Include the critical information in the drawing.

# Slab on Grade w/ICF Stem Wall

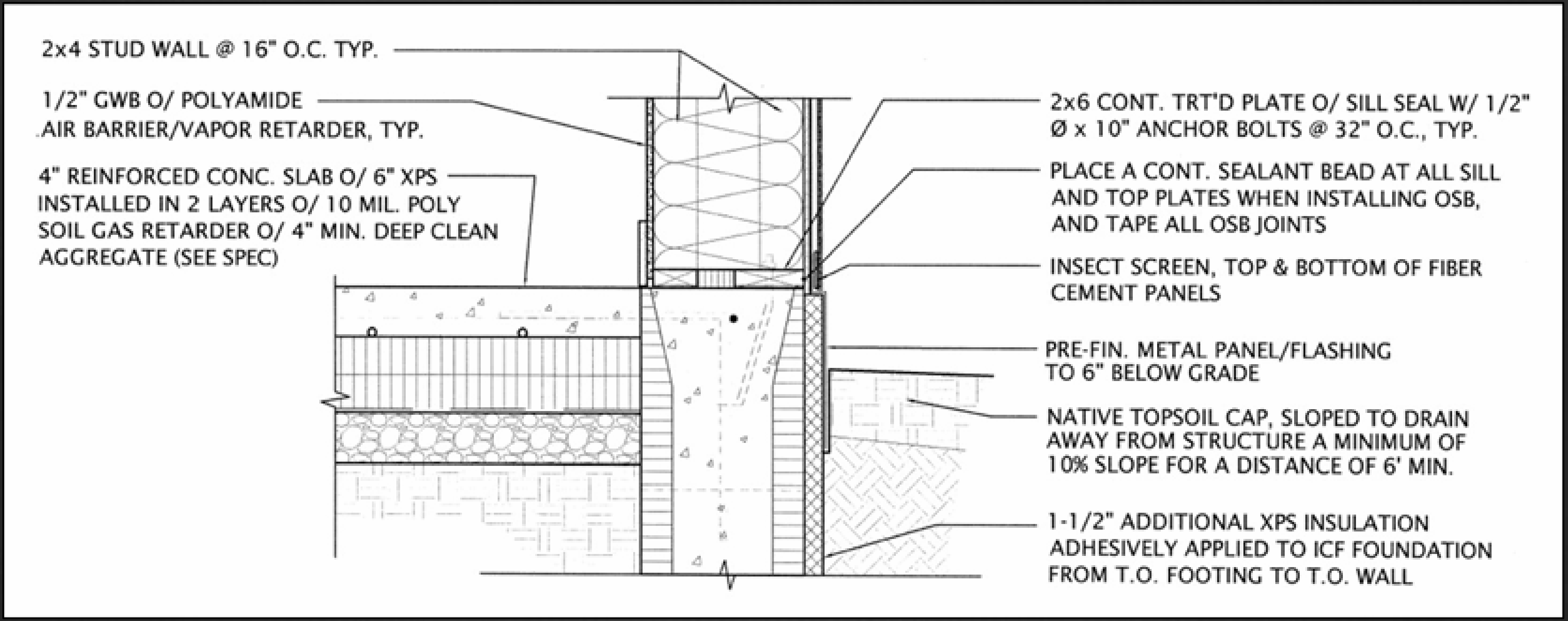



Both walls are bearing. Thermal bridging might be an issue here.

# Frost Protected Slab w/ICF Stem Wall



# Variation: Slab on Grade w/ICF Stem Wall for Double Stud Wall Assembly



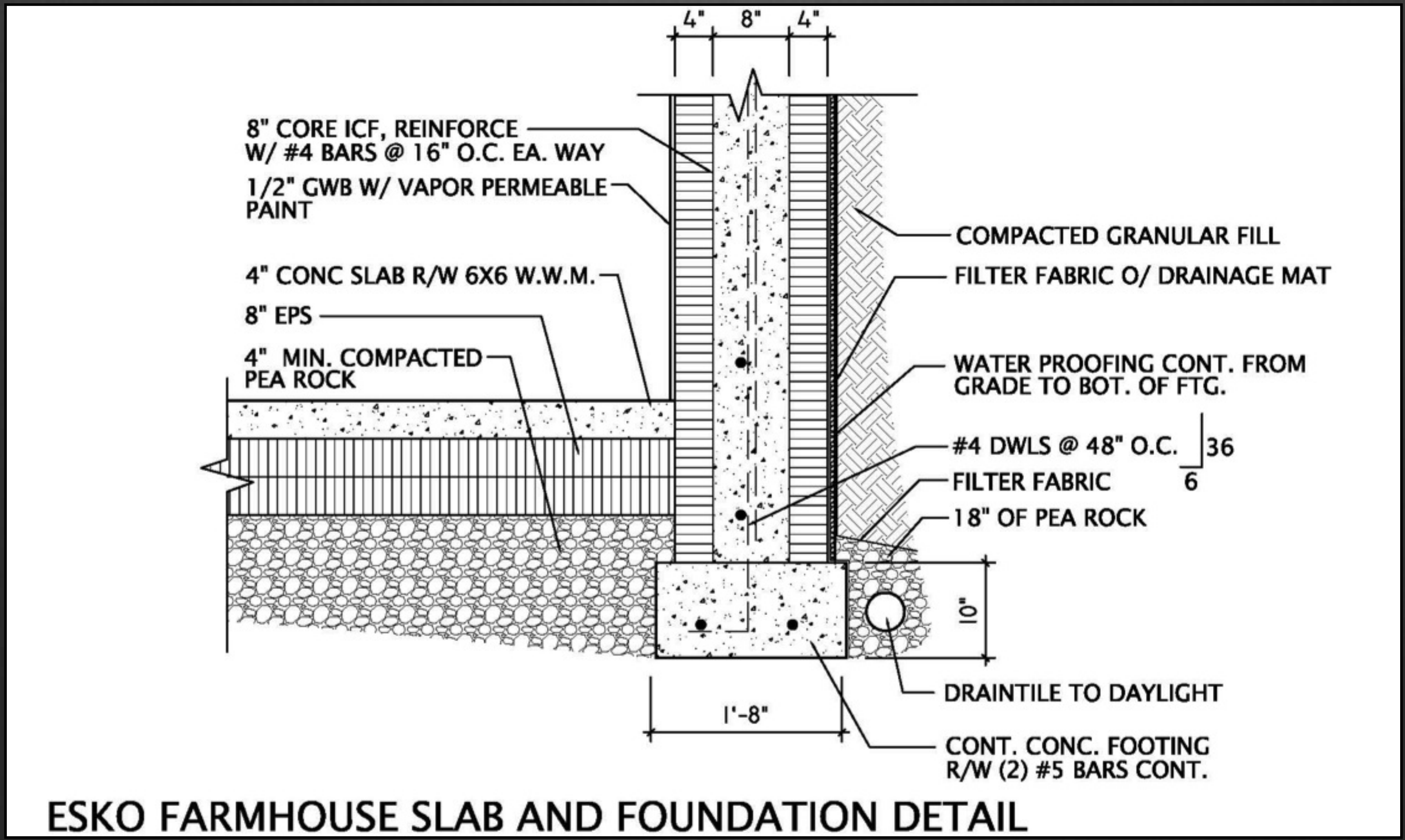

Both walls are still bearing. Additional foam added to exterior.

# A Low-energy Basement

# ICF = easy super-insulation


ICF wall can be built with standard-order forms for R-22 – R-40

# ICF walls + super-insulated slab



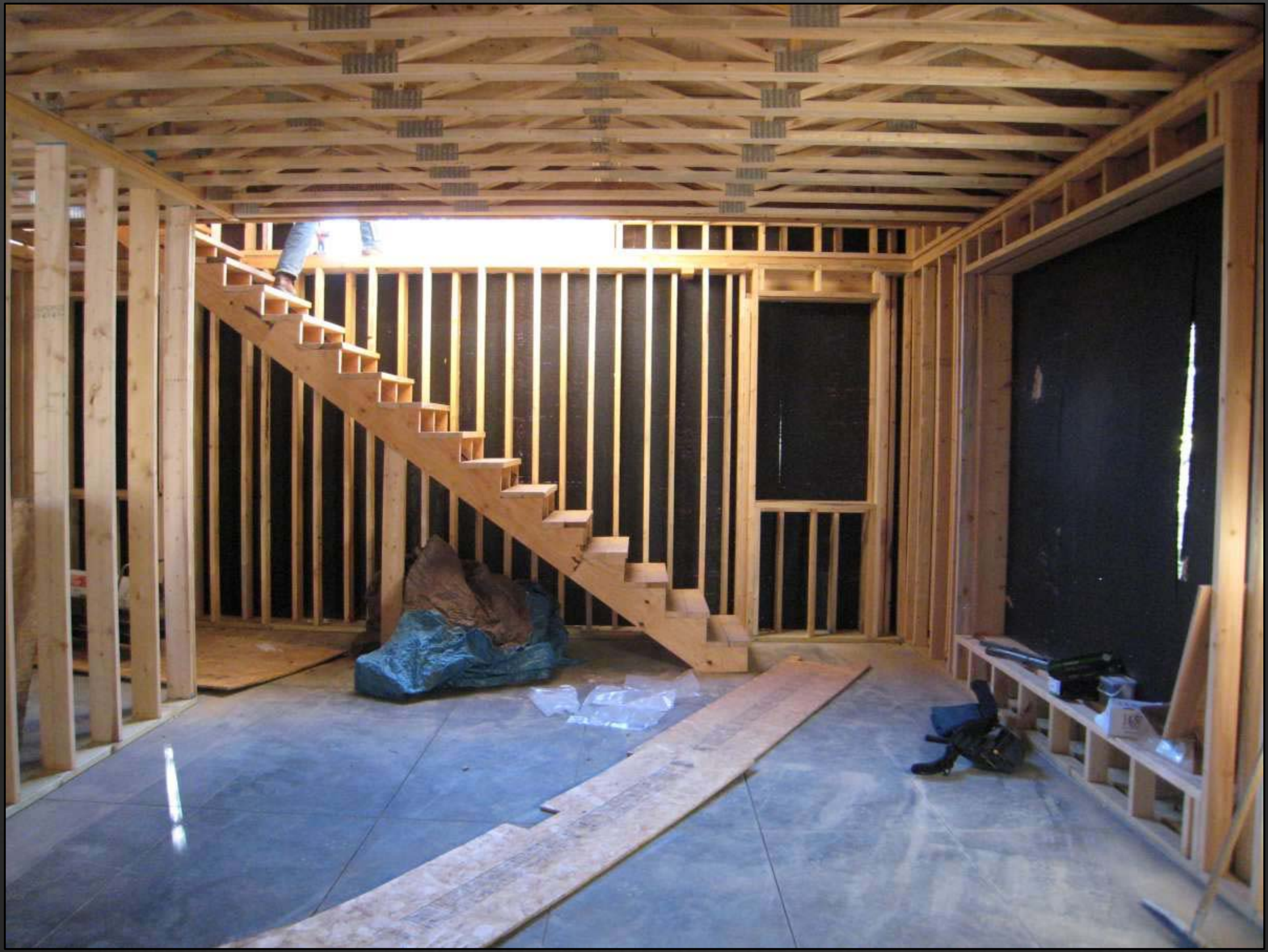

Underslab insulation : usually 6”-8” EPS for R 24 – R-32

2012 IECC requires R-10* in climate zone 7 (*sort of)

# Heat, Air and Moisture at the Slab

Seal Penetrations
Insulate Under Bearing Walls/Posts
Higher psi under bearing walls, points

# Walls, Walls, Walls



# Double Stud Walls

- Familiar assemblies, common materials
- Usually filled with blown in insulation
- There are variations in assembly, using the same principle.

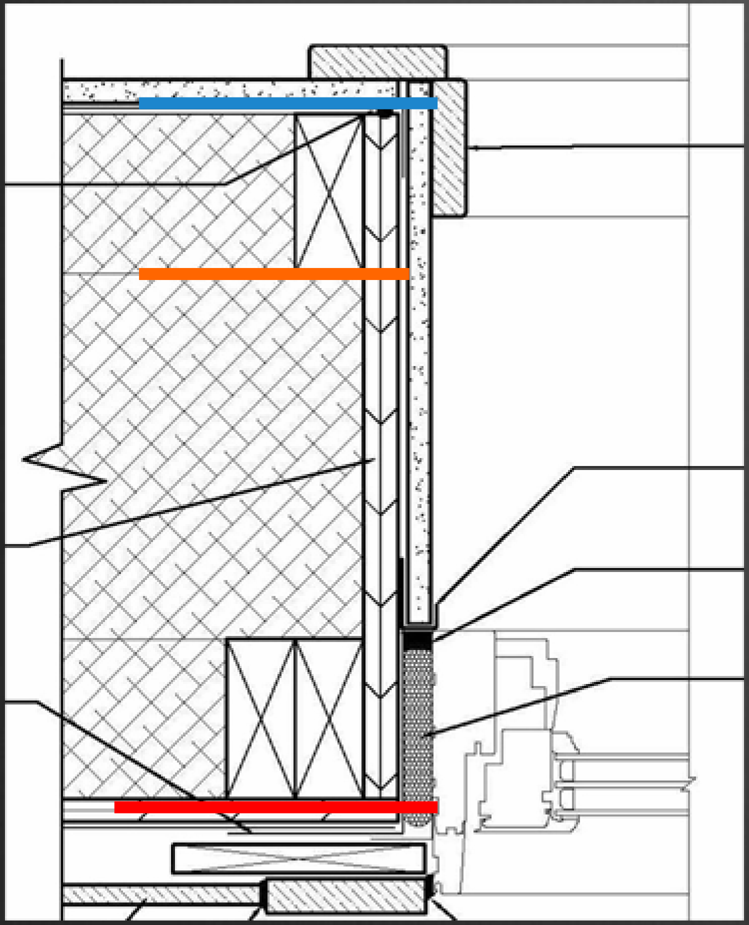
# Double Stud Walls

- With one approach to details, you can vary the thickness and achieve an overall R-value that “fits.”
- In a cold climate, 10”- 16” thick makes sense for low energy construction.
- This assembly has a history of working well in super-insulation, but …

# Double stud – key issues

- Locating the air barrier and keeping it robust.
- Because the sheathing will be colder in winter, wall should be able to dry to the outside.
- Plywood and structural fiberboard are usually a better sheathing choice than OSB.
- A gap between sheathing and siding is ideal.
- Fire blocking is required by code.
- Choosing the bearing wall (one or both).
- Assembly sequence, especially in a cold climate.

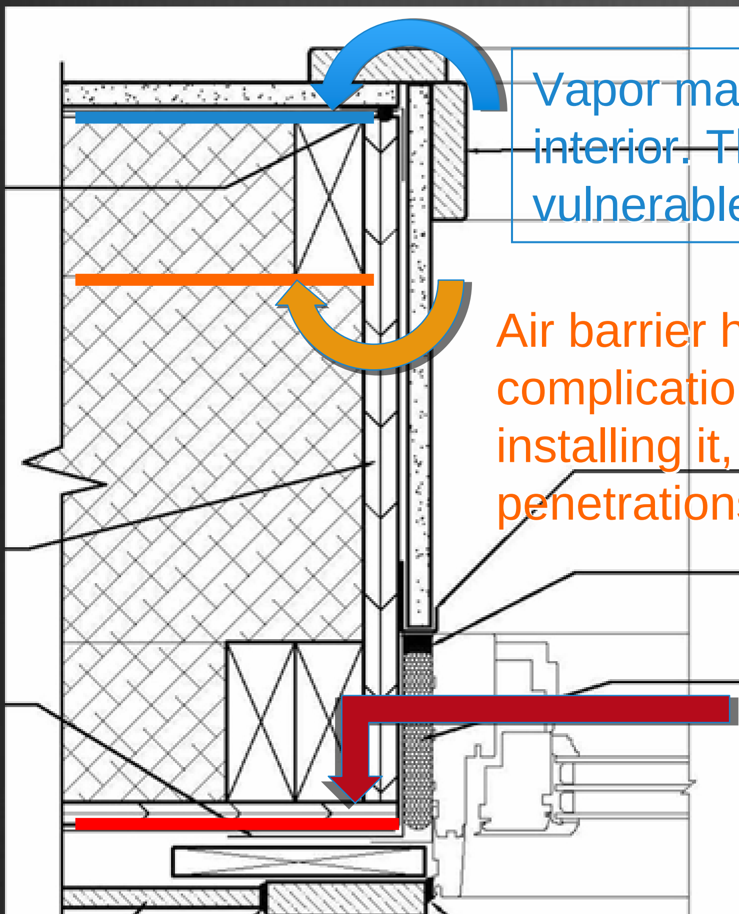
# Air and Moisture Management



OPTIONS

- Interior sheet polyamide
- Interior OSB
- Exterior Sheathing taped
- Use of Spray Foam
- Interior “cavity” wall w/OSB air barrier
- Interior “cavity” wall with membrane air barrier
- Larsen truss or I-joist outboard

# Air and Moisture Management

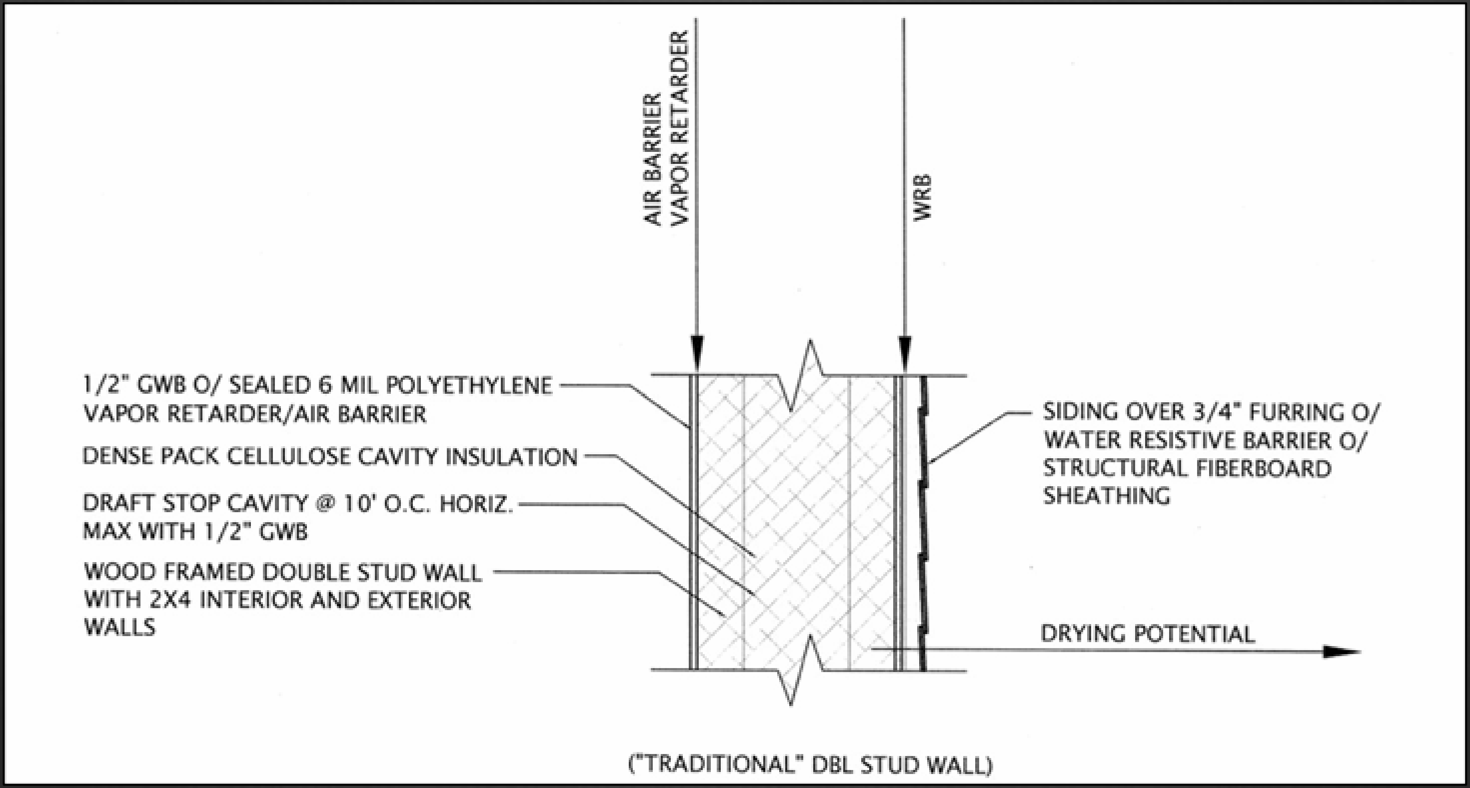


Vapor management usually best to the interior. The air barrier can be here, but it is vulnerable to modifications to the interior.

Air barrier here might be ideal but can present complications for construction assembly – installing it, insulating both sides, sealing penetrations, inspecting continuity …

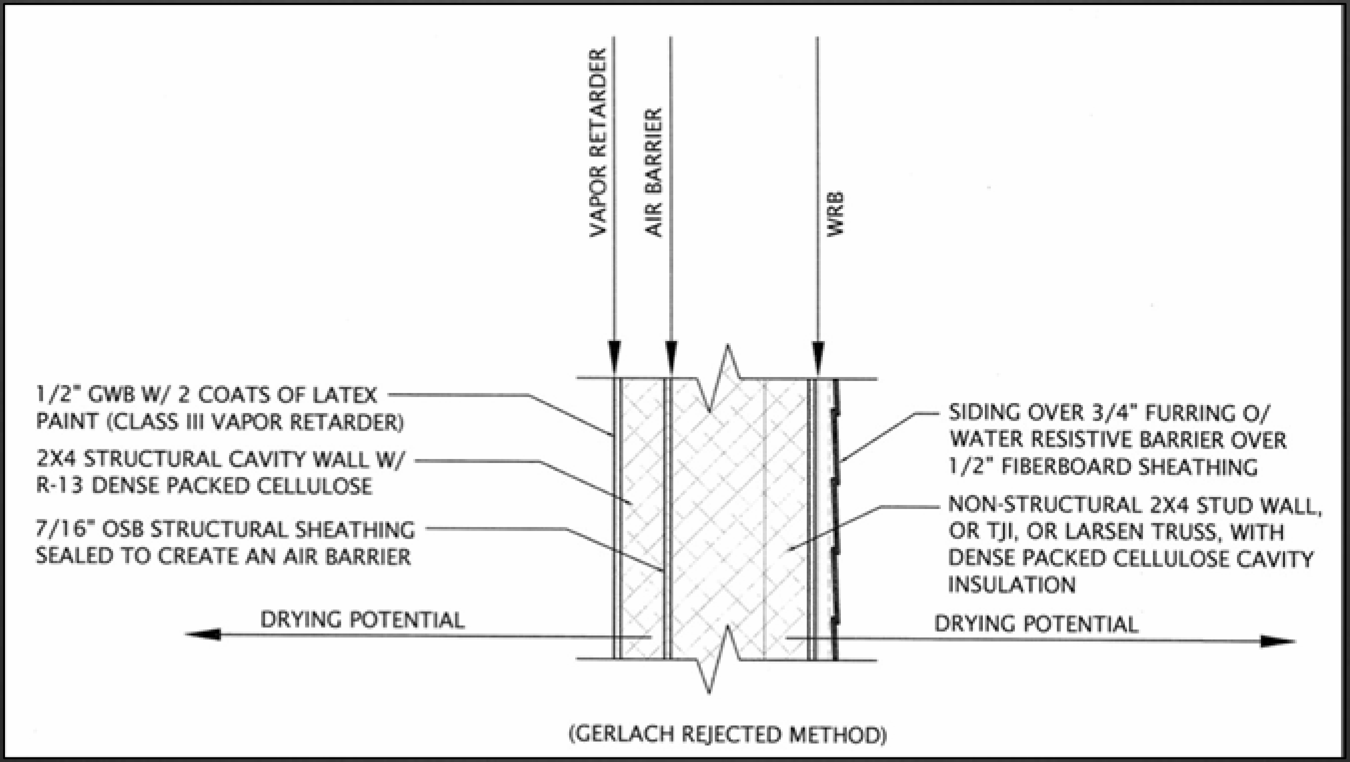
Maybe the air barrier goes here? But what about the cold sheathing. If the air barrier is here, a class II vapor retarder should go to the inside.

# Evolution of a cold climate double stud wall.



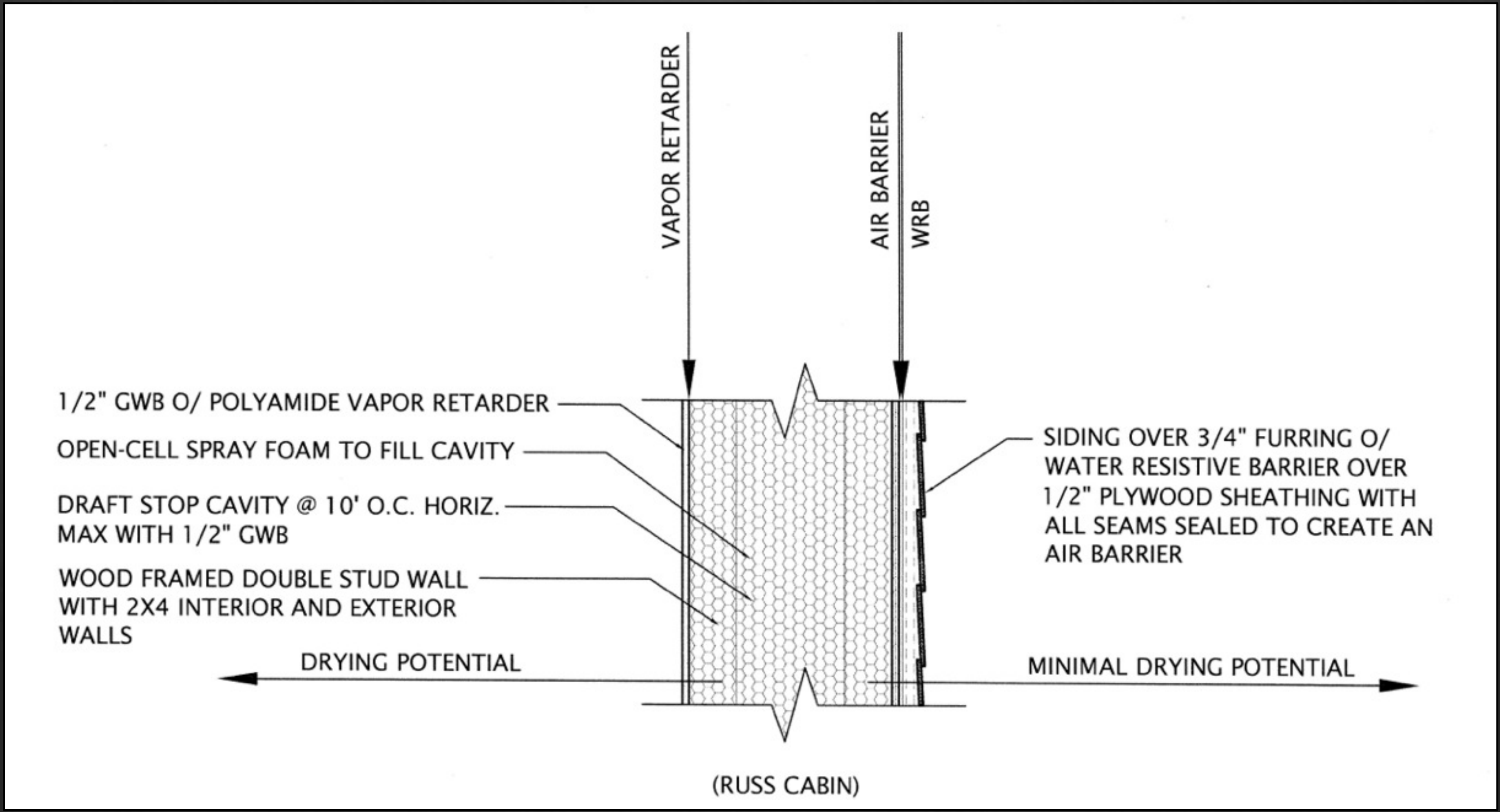

What's wrong with this picture?

# Evolution of a cold climate double stud wall.



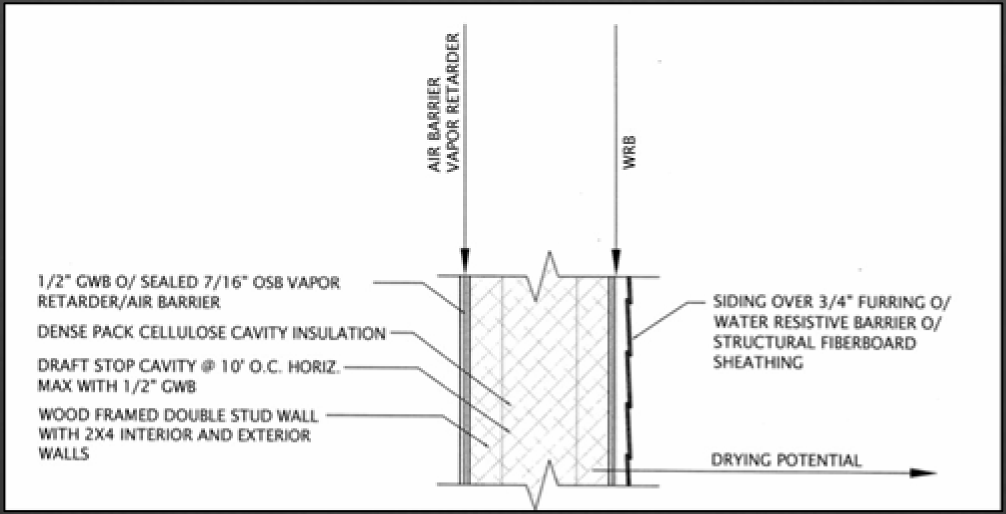

- A really good idea, especially from a building science and long-term durability perspective.
- But … hard to construct for a 2-story home with a walk-out basement. And winter conditions … welcome to a cold climate.

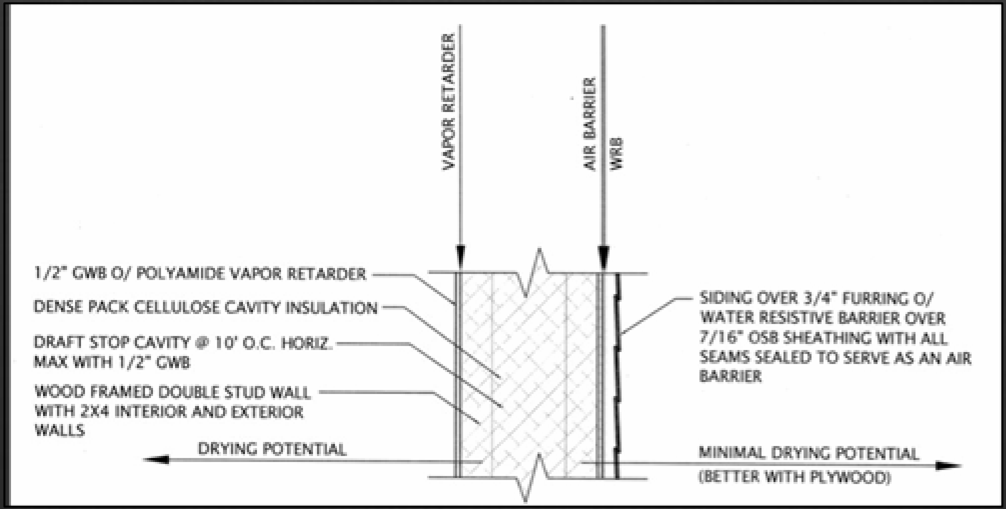
# Evolution of a cold climate double stud wall.



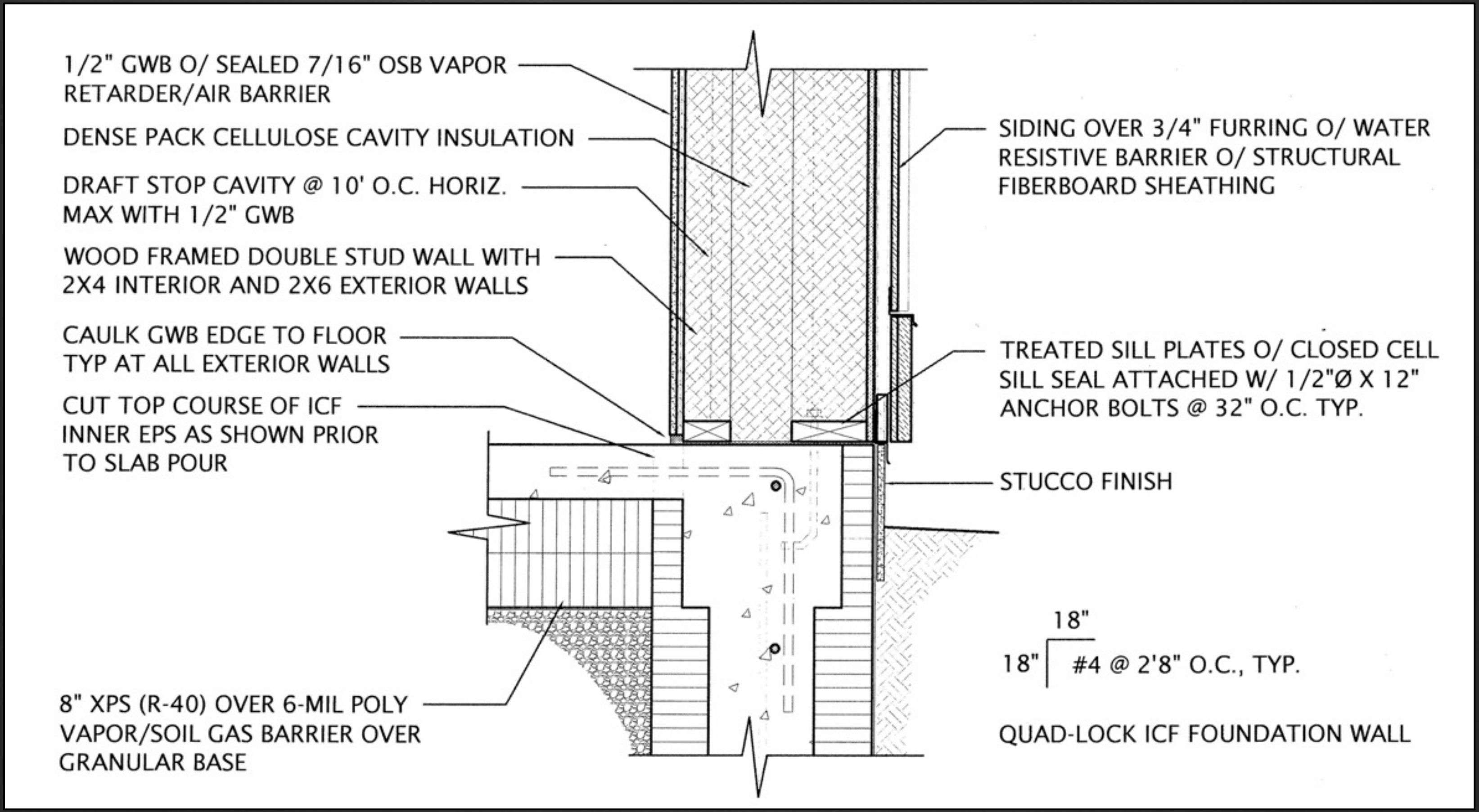

Carter Scott’s wall, but with interior polyamide as vapor retarder.

# Evolution of a cold climate double stud wall. Variations on a theme.

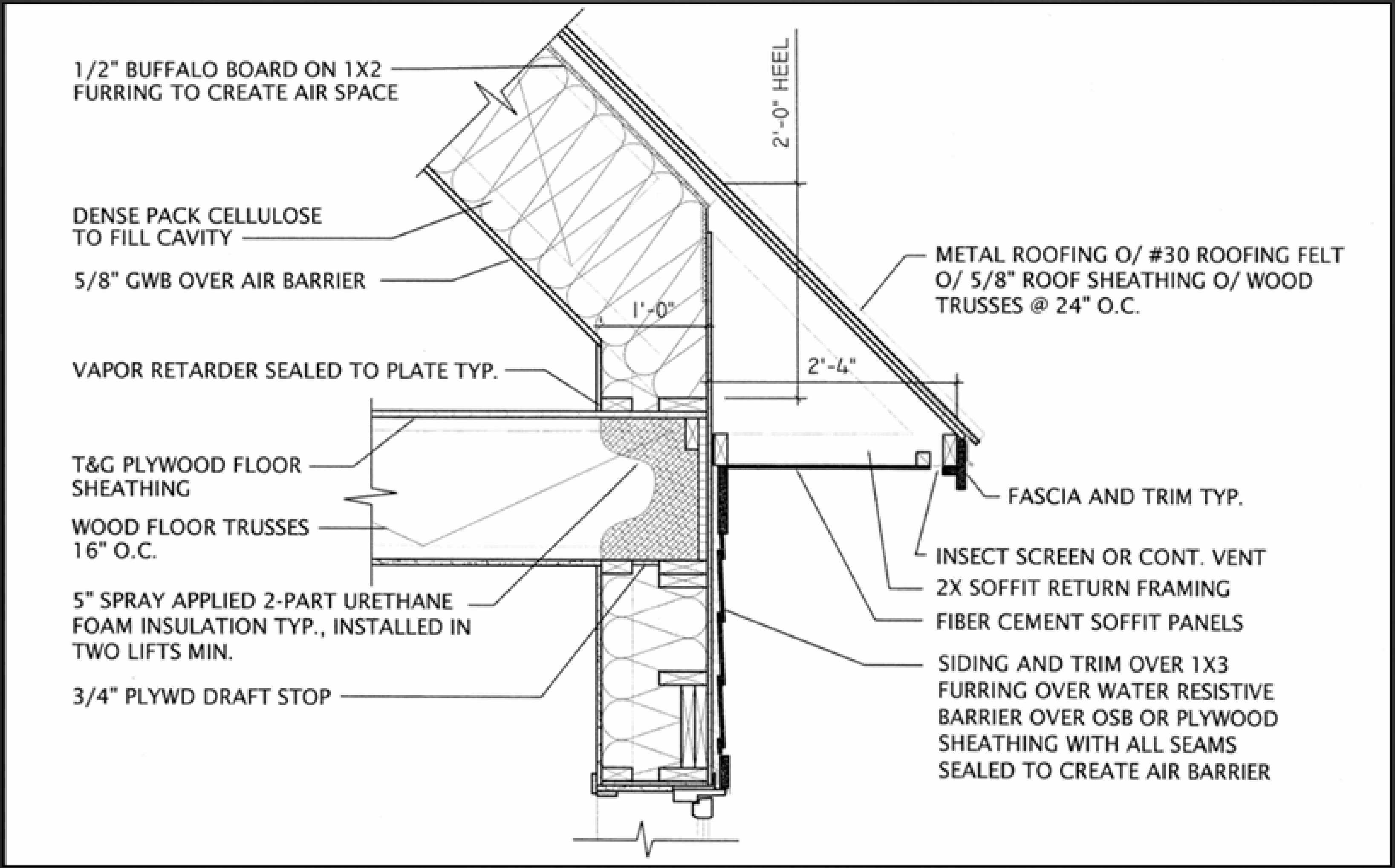


# Wall details – transitions can be tricky



# Transitions: wall to floor to roof

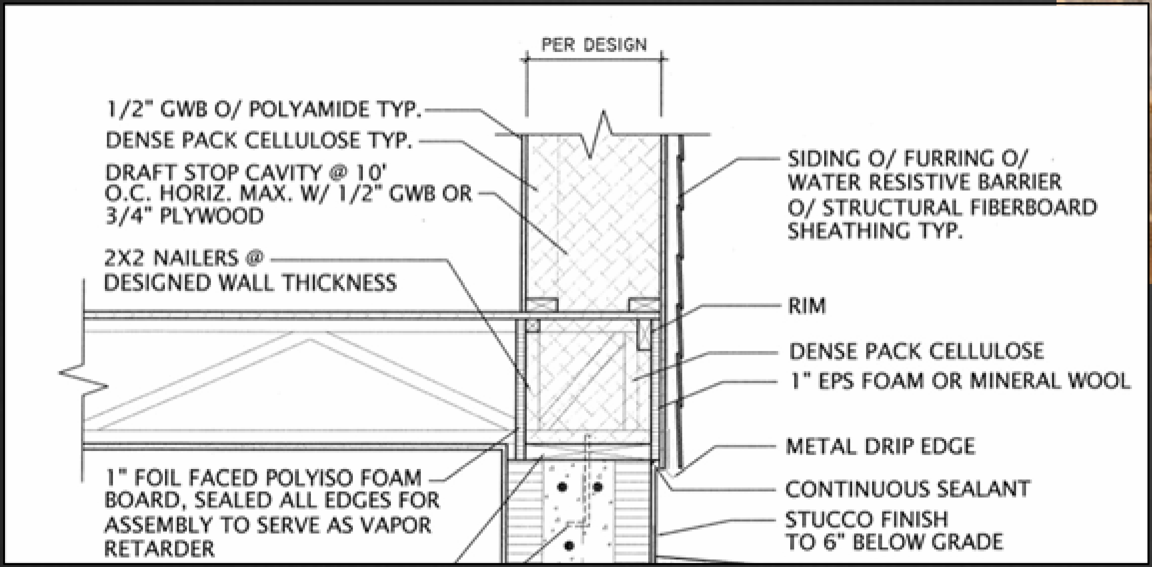


# Alternate super-insulated Rim Assembly

Insulating the rim with cellulose was easier than we imagined.

But usually we use 2-3 applications of 2-part closed cell urethane spray foam

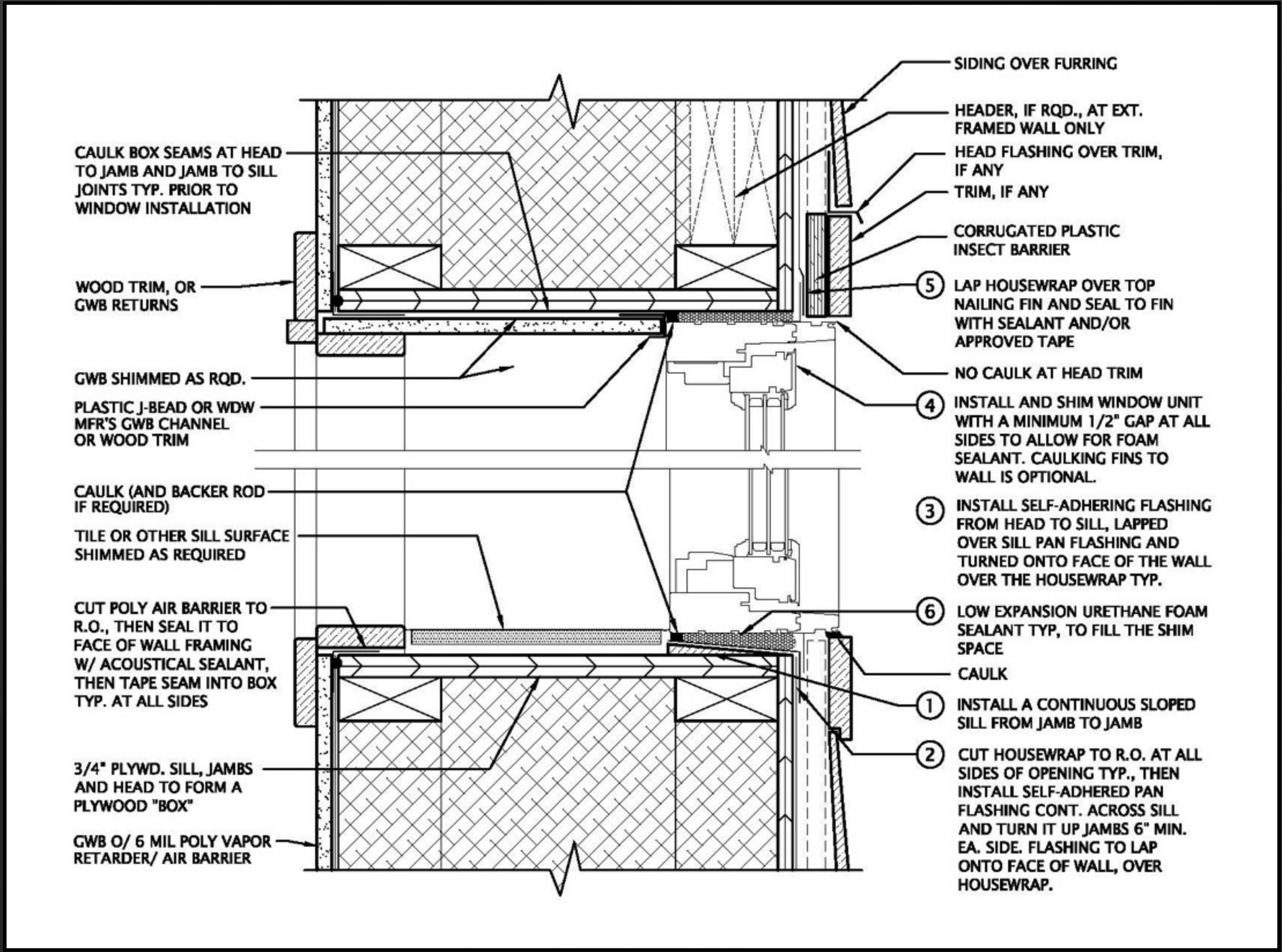
This detail was labor intensive in order to maintain the air barrier, but effective.



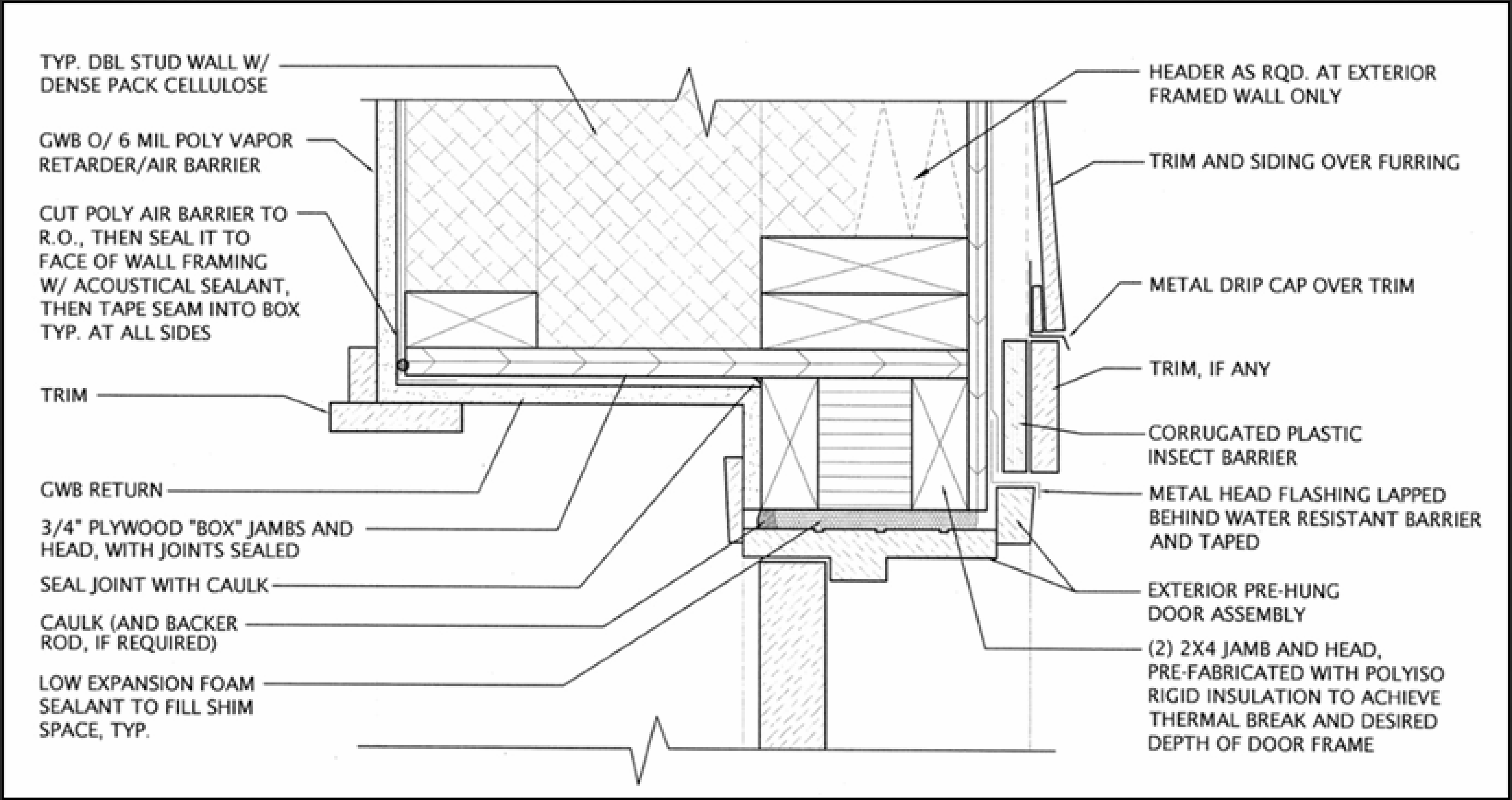
# Window and door framing

Openings require special framing details, not complicated if thought out in advance and drawn.

# Window to the outside with box frame



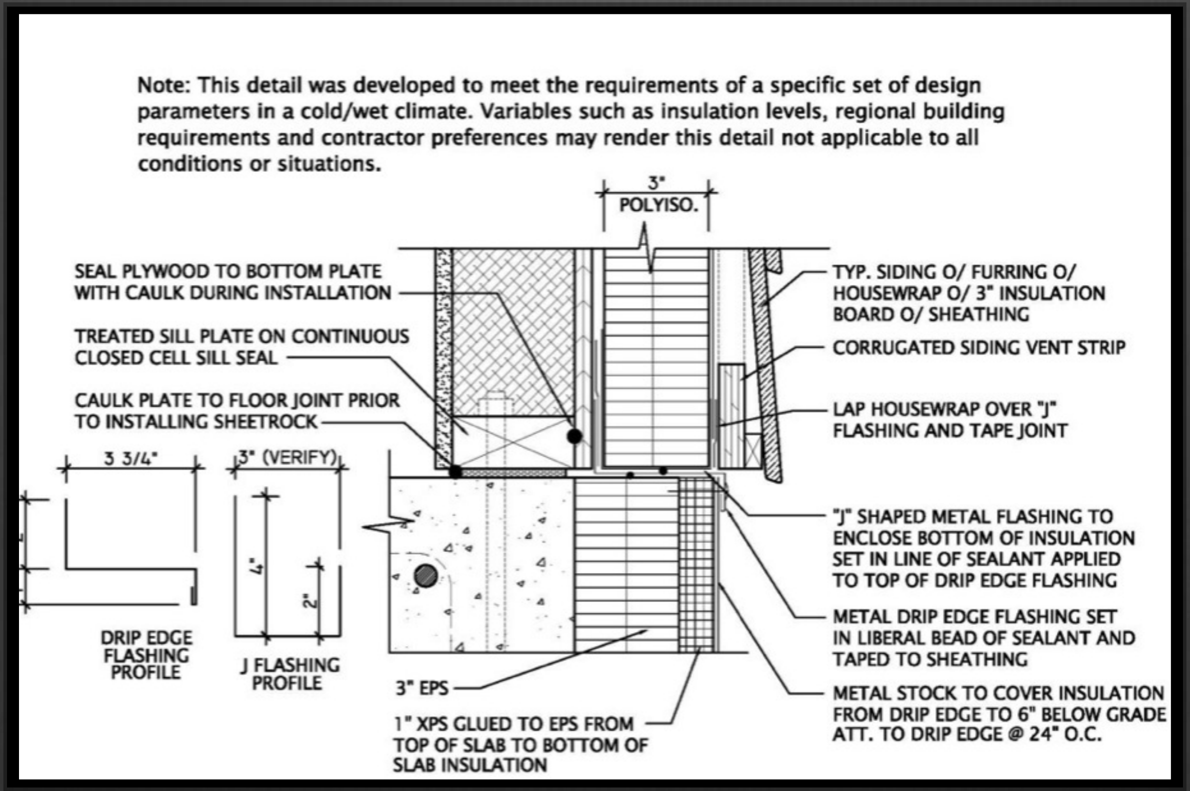
# Door at the Outer Wall for best water management



# The results can be dramatic

# Single Stud Walls with Exterior Foam Sheathing

Variations on Joe Lstiburek’s “Perfect Wall.”




Thermal bridging readily addressed.

Structure is protected and kept warm.

Integrates well with vertical slab edge insulation.

Can frame with 2 x 6 or 2 x 4 stud walls.

Board sheathing can easily be the air barrier, rigid and protected.

# Rigid sheathing as the air barrier

www.diychatroom.com

Plywood or OSB seams are sealed with caulk, tape, or liquid.

ZIP sheathing proprietary system has benefits.

Beware instances of some OSB failing air tightness.

Sheathing must be sealed to framing intersections for continuity:

- top and bottom plates, trusses, box frames for windows and doors

# Use enough foam sheathing to allow a Class III vapor retarder

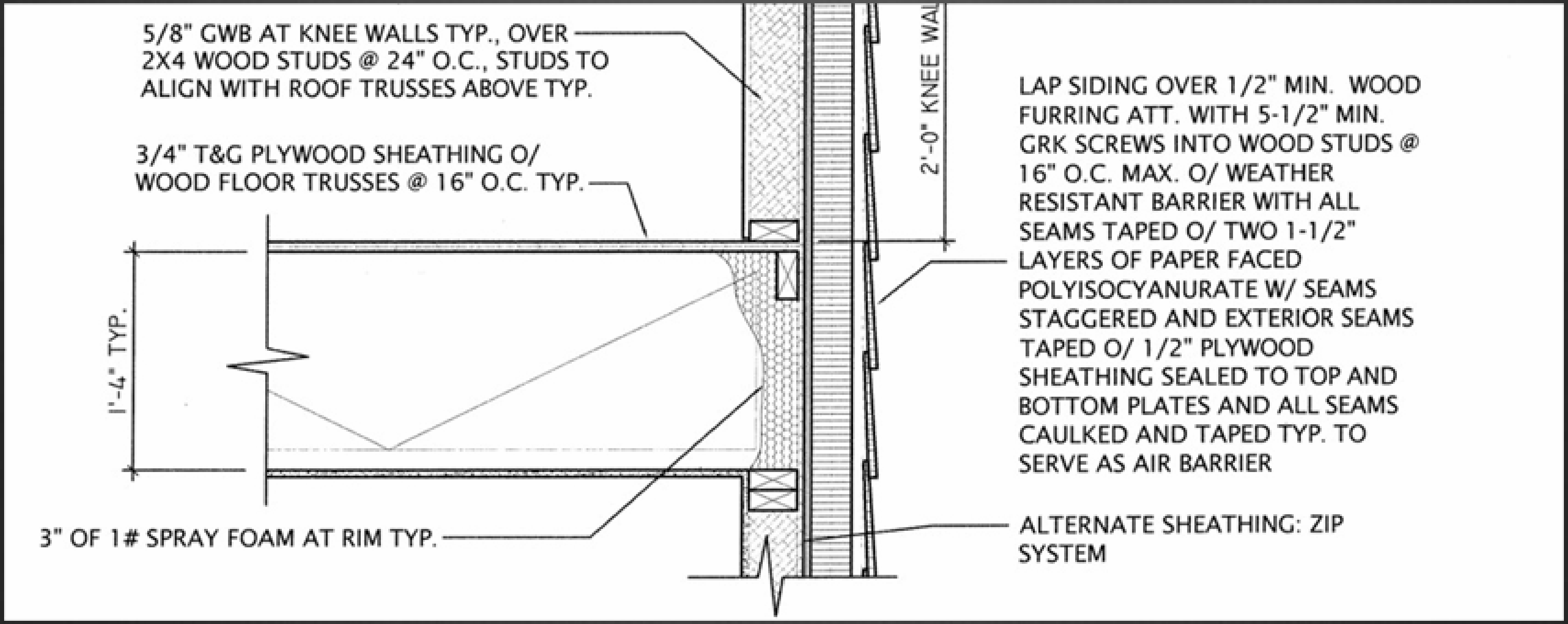
| Zone | Class III vapor retarders permitted for: |
|---|---|
| Marine 4 | Vented cladding over OSB<br>Vented cladding over plywood<br>Vented cladding over fiberboard<br>Vented cladding over gypsum<br>Insulated sheathing with R-value >= 2.5 over 2x4 wall<br>Insulated sheathing with R-value >= 3.75 over 2x6 wall |
| 5 | Vented cladding over OSB<br>Vented cladding over plywood<br>Vented cladding over fiberboard<br>Vented cladding over gypsum<br>Insulated sheathing with R-value >= 5 over 2x4 wall<br>Insulated sheathing with R-value >= 7.5 over 2x6 wall |
| 6 | Vented cladding over fiberboard<br>Vented cladding over gypsum<br>Insulated sheathing with R-value >= 7.5 over 2x4 wall<br>Insulated sheathing with R-value >= 11.25 over 2x6 wall |
| 7 and 8 | Insulated sheathing with R-value >= 10 over 2x4 wall<br>Insulated sheathing with R-value >= 15 over 2x6 wall |

# What kind of foam and how?

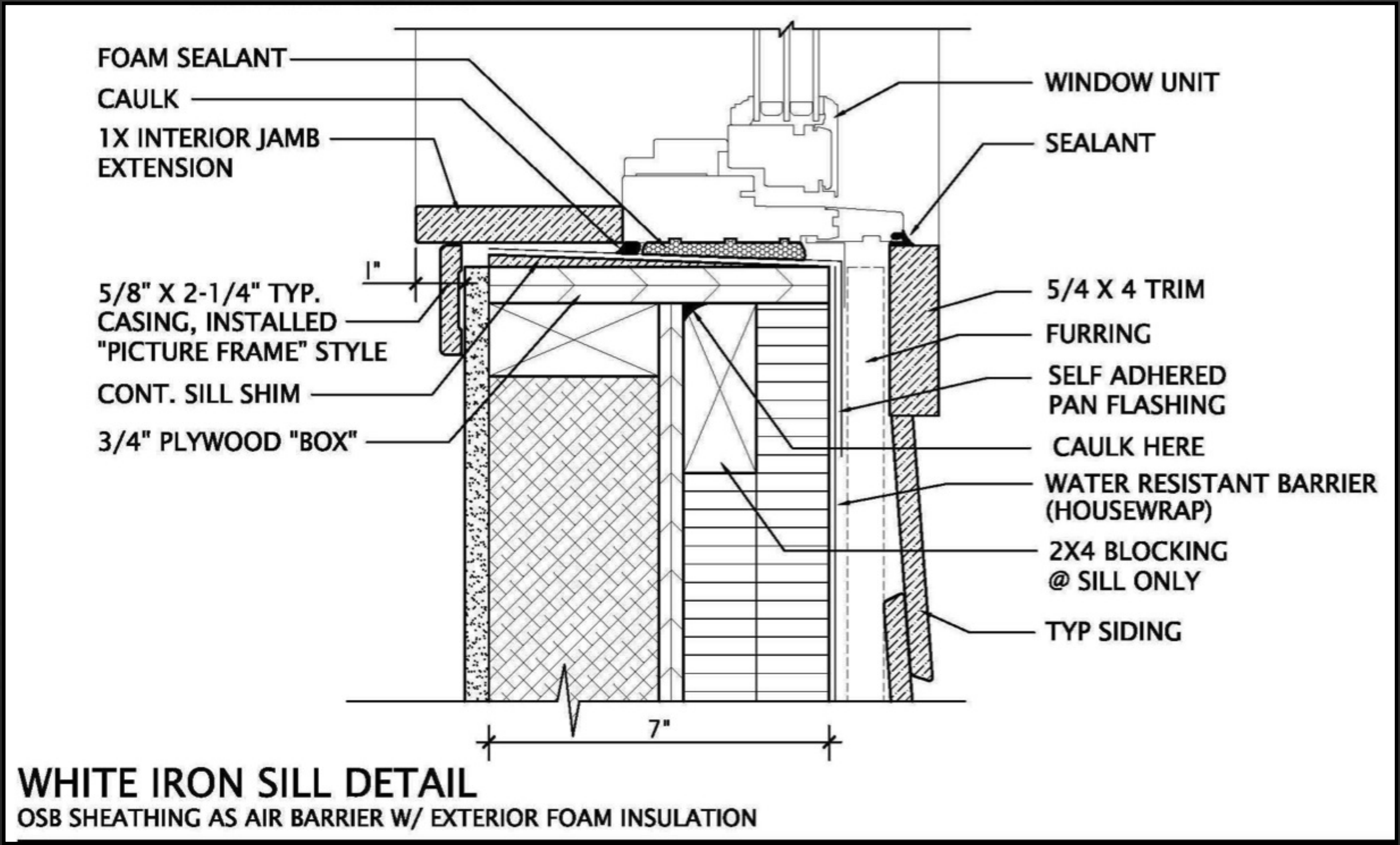
Photo: Marc Rosenbaum/GBA

- Polyiso may not be best in a cold climate
- Mineral wool gaining popularity.
- XPS is familiar to builders, but …
- EPS can be hard to work with.
- Consider nailbase panels.
- Two layers with staggered seams is still probably the safest route.

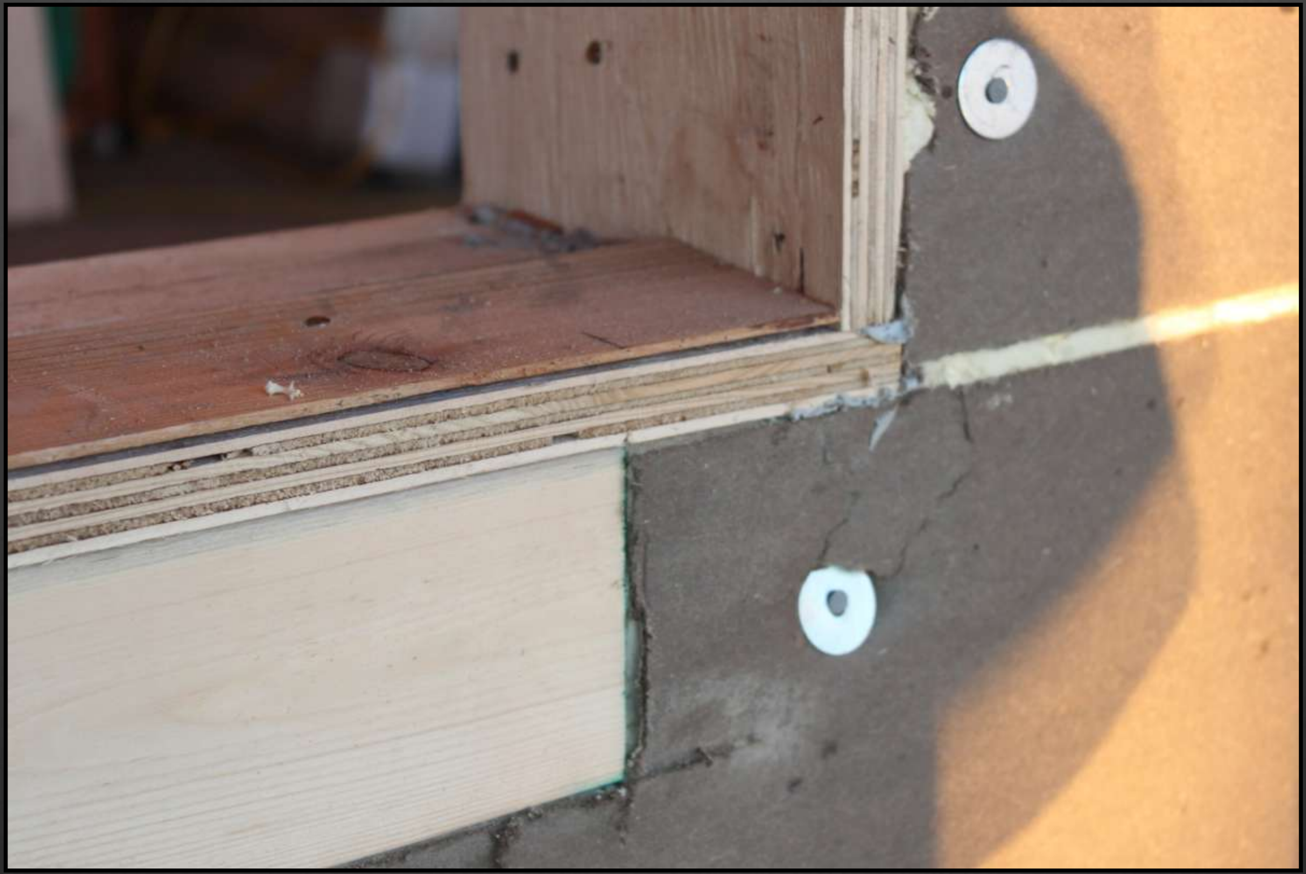
# Certain things need attention




- Long screws to fasten siding through furring
- Extra planning at corners to find solid fastening
- Deck attachment details can get tricky

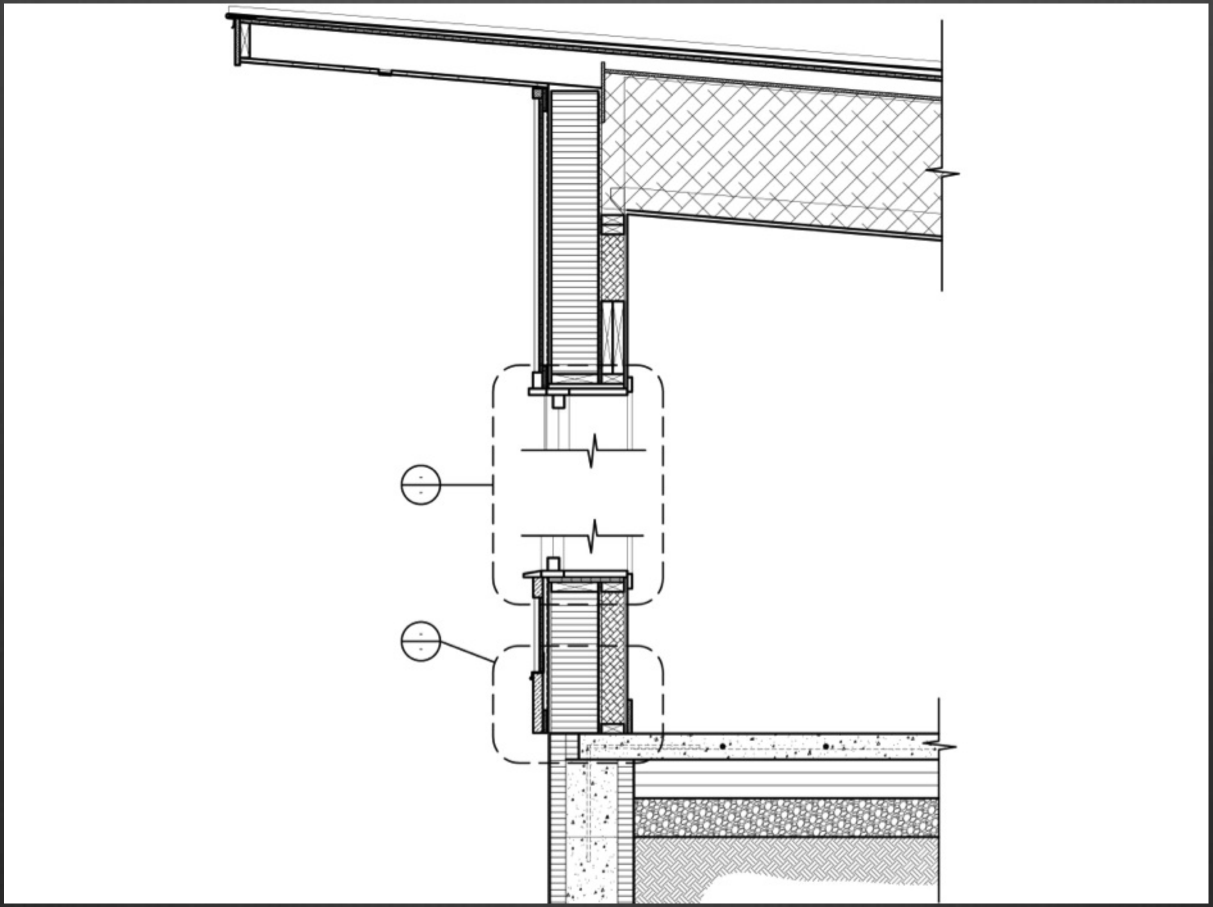



With 3” or more of foam sheathing, may need wood support under windows

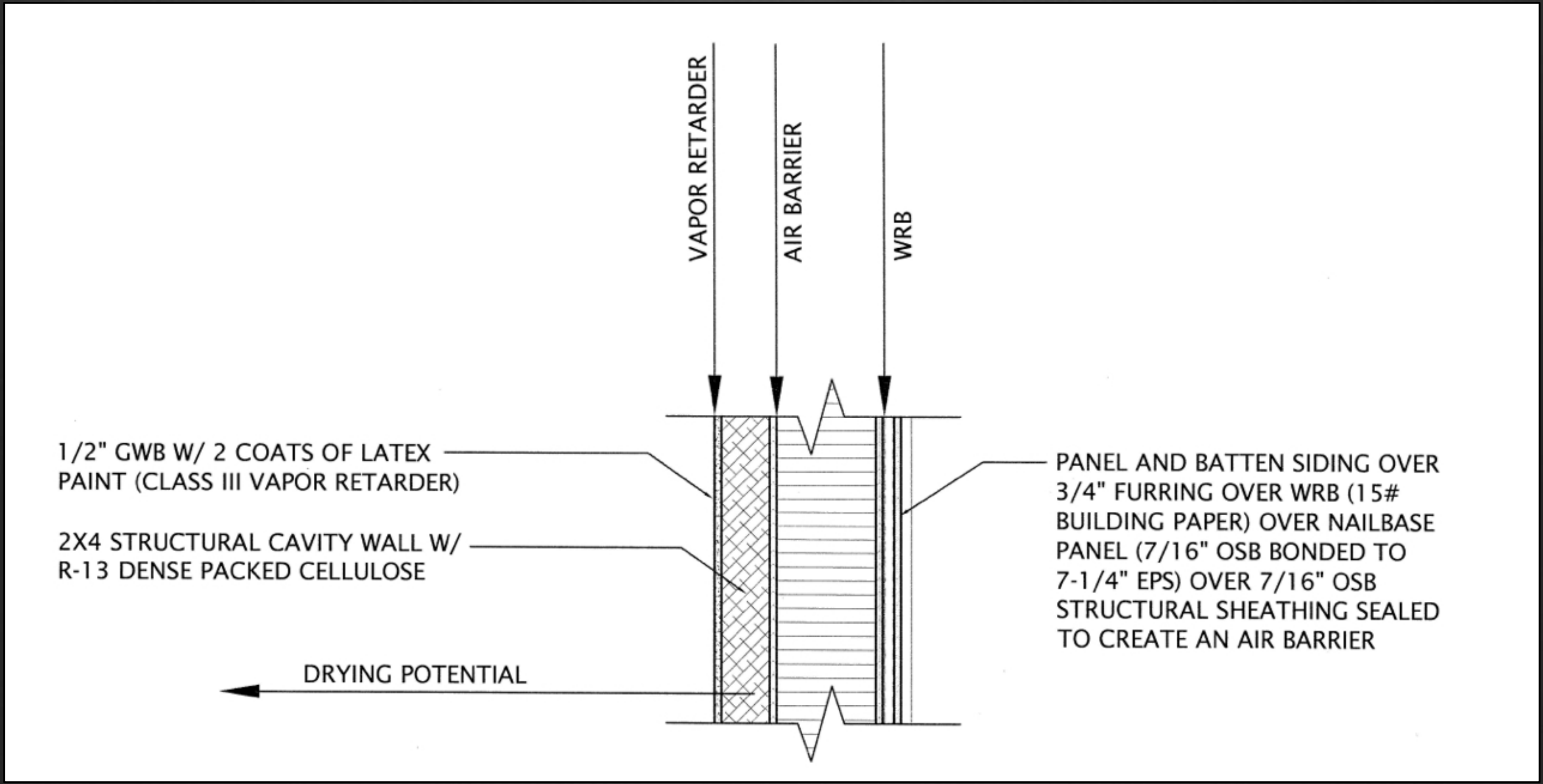


- 2 layers of foam are better than one
- If board sheathing is the air barrier, you don't need to tape foam joints, but large gaps should be foamed

# Evolving single stud + foam

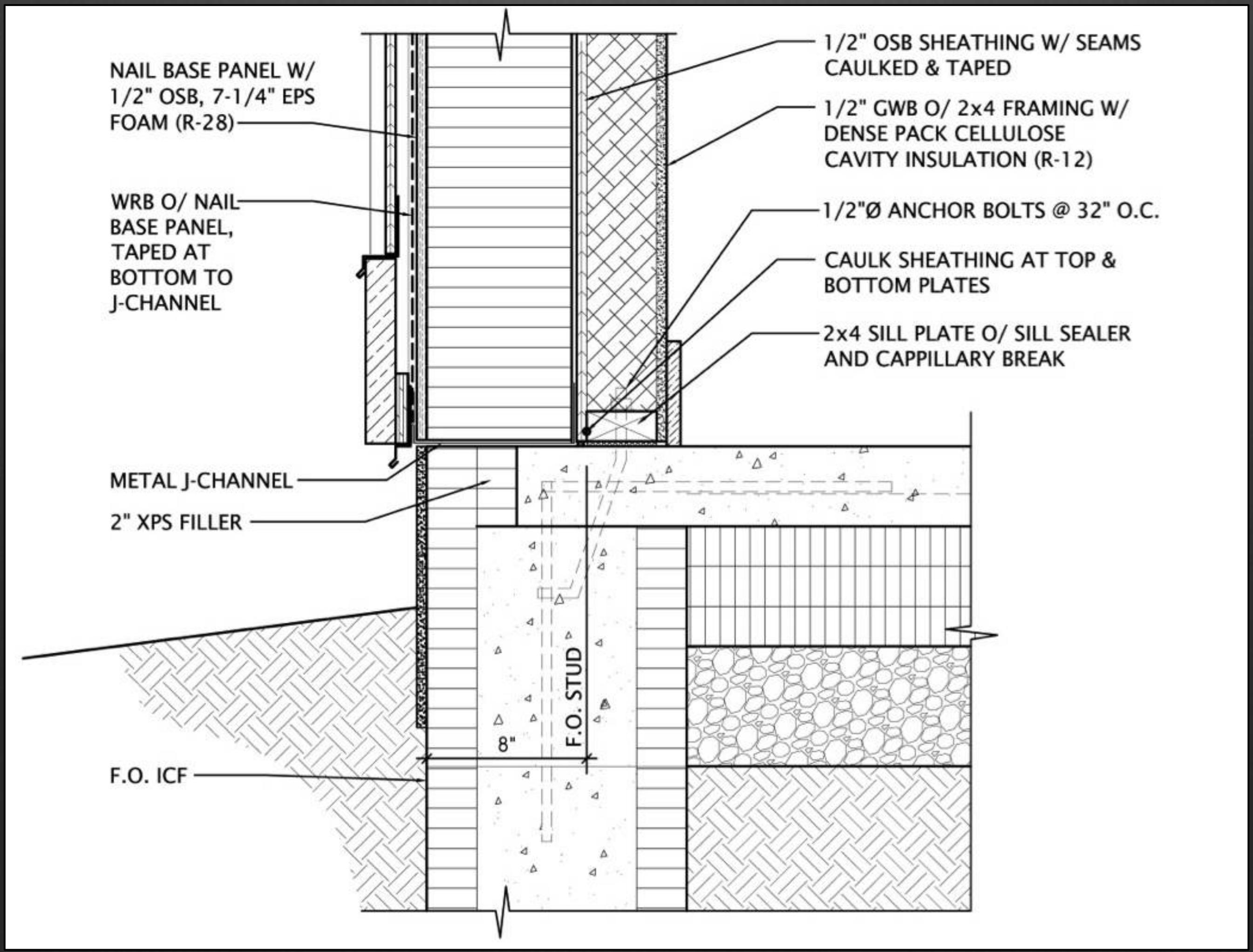


# (S)IP Hybrid

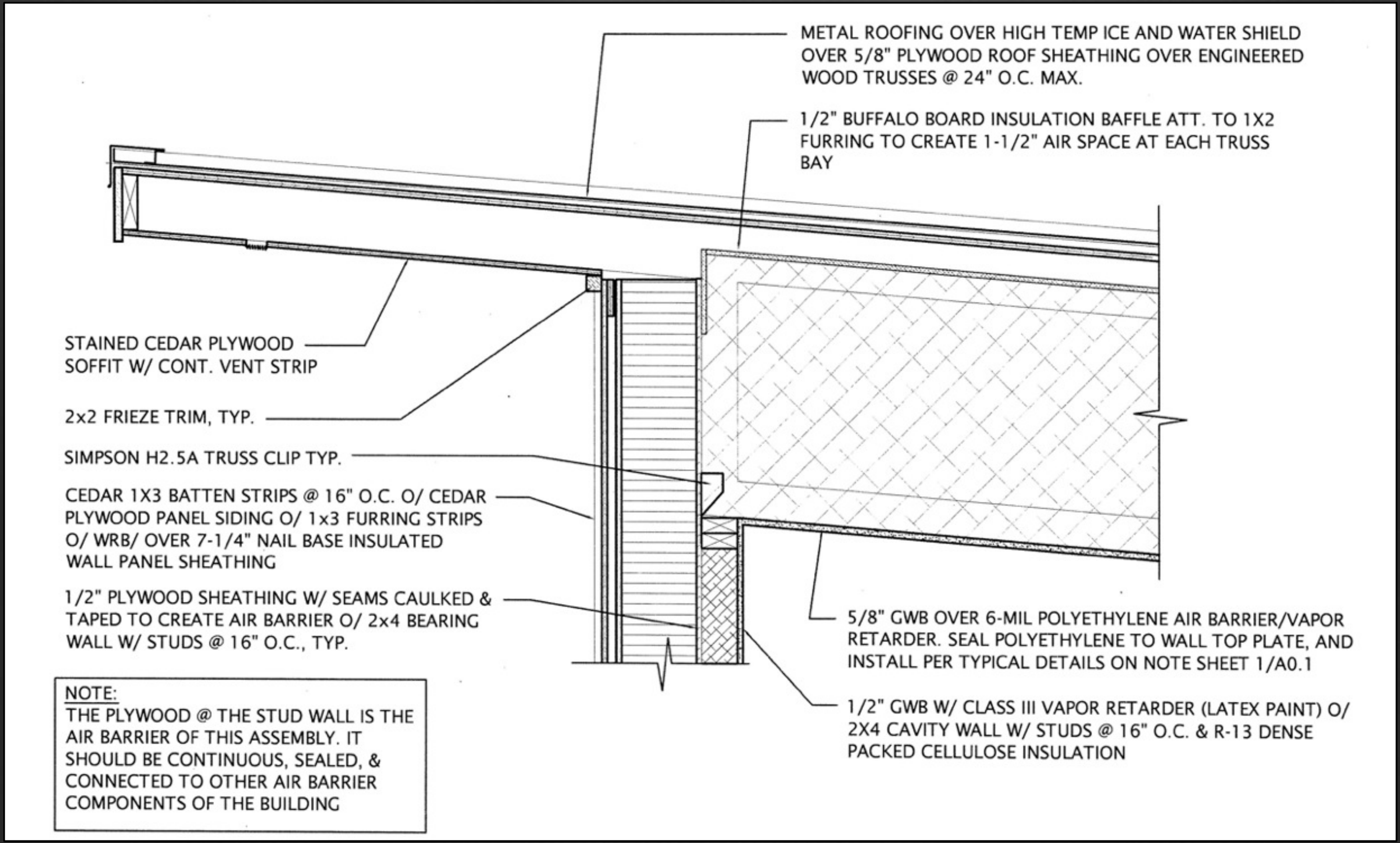


VAPOR RETARDER
AIR BARRIER
WRB
1/2" GWB W/ 2 COATS OF LATEX PAINT (CLASS III VAPOR RETARDER)
2X4 STRUCTURAL CAVITY WALL W/ R-13 DENSE PACKED CELLULOSE
DRYING POTENTIAL
PANEL AND BATTEN SIDING OVER 3/4" FURRING OVER WRB (15# BUILDING PAPER) OVER NAILBASE PANEL (7/16" OSB BONDED TO 7-1/4" EPS) OVER 7/16" OSB STRUCTURAL SHEATHING SEALED TO CREATE AN AIR BARRIER

# (S)IP Hybrid


NAIL BASE PANEL W/ 1/2" OSB, 7-1/4" EPS FOAM (R-28)
WRB O/ NAIL BASE PANEL, TAPED AT BOTTOM TO J-CHANNEL
METAL J-CHANNEL
2" XPS FILLER
F.O. ICF
1/2" OSB SHEATHING W/ SEAMS CAULKED & TAPED
1/2" GWB O/ 2x4 FRAMING W/ DENSE PACK CELLULOSE CAVITY INSULATION (R-12)
1/2"Ø ANCHOR BOLTS @ 32" O.C.
CAULK SHEATHING AT TOP & BOTTOM PLATES
2x4 SILL PLATE O/ SILL SEALER AND CAPPILLARY BREAK
F.O. STUD
8"

# (S)IP Hybrid



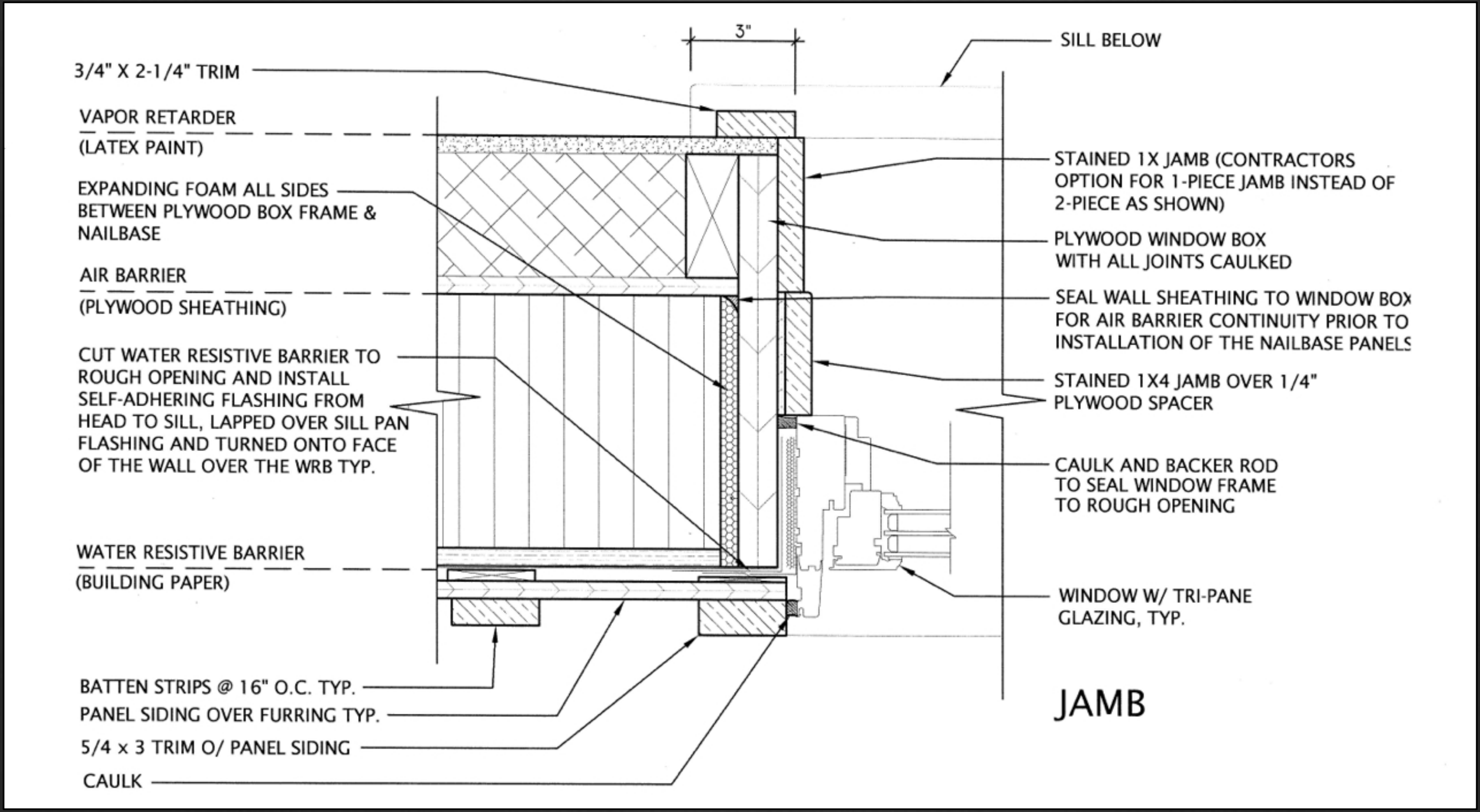
METAL ROOFING OVER HIGH TEMP ICE AND WATER SHIELD OVER 5/8" PLYWOOD ROOF SHEATHING OVER ENGINEERED WOOD TRUSSES @ 24" O.C. MAX.
1/2" BUFFALO BOARD INSULATION BAFFLE ATT. TO 1X2 FURRING TO CREATE 1-1/2" AIR SPACE AT EACH TRUSS BAY
STAINED CEDAR PLYWOOD SOFFIT W/ CONT. VENT STRIP
2x2 FRIEZE TRIM, TYP.
SIMPSON H2.5A TRUSS CLIP TYP.
CEDAR 1X3 BATTEN STRIPS @ 16" O.C. O/ CEDAR PLYWOOD PANEL SIDING O/ 1x3 FURRING STRIPS O/ WRB/ OVER 7-1/4" NAIL BASE INSULATED WALL PANEL SHEATHING
1/2" PLYWOOD SHEATHING W/ SEAMS CAULKED & TAPED TO CREATE AIR BARRIER O/ 2x4 BEARING WALL W/ STUDS @ 16" O.C., TYP.
5/8" GWB OVER 6-MIL POLYETHYLENE AIR BARRIER/VAPOR RETARDER. SEAL POLYETHYLENE TO WALL TOP PLATE, AND INSTALL PER TYPICAL DETAILS ON NOTE SHEET 1/A0.1
1/2" GWB W/ CLASS III VAPOR RETARDER (LATEX PAINT) O/ 2X4 CAVITY WALL W/ STUDS @ 16" O.C. & R-13 DENSE PACKED CELLULOSE INSULATION
NOTE:
THE PLYWOOD @ THE STUD WALL IS THE AIR BARRIER OF THIS ASSEMBLY. IT SHOULD BE CONTINUOUS, SEALED, & CONNECTED TO OTHER AIR BARRIER COMPONENTS OF THE BUILDING

# Windows

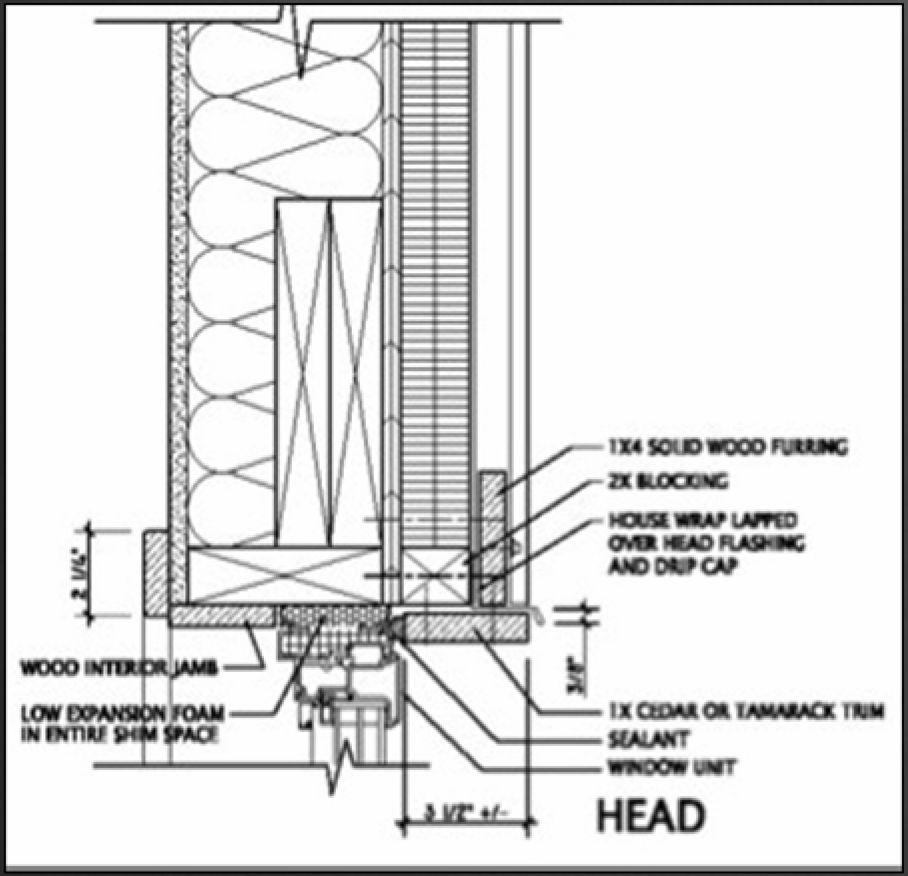
# Windows for a cold climate

1. High solar gain
   - Min 0.5 glazing SHGC or
   - 0.4 whole window value
2. High thermal performance
   - MAX. overall U-value of 0.24
   - Don't lose more heat from the house than heat gained from the sun
3. High visible transmittance
   - It's cold and dark for many months
   - I look for min. glazing VT of .6
4. Condensation resistance
   - Frame with some insulating value
   - Warm edge spacers

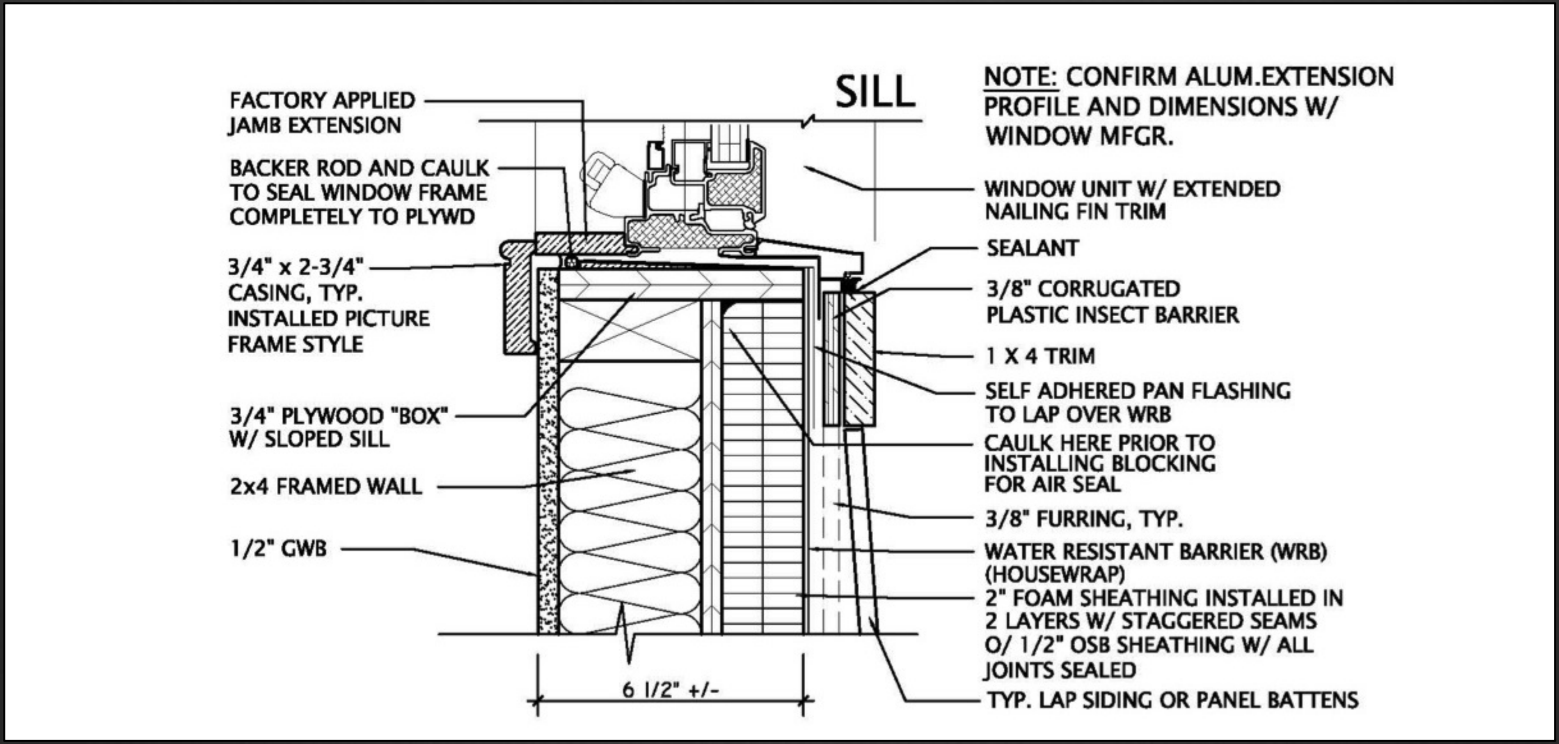
# Window Details with Detail



# Inset window in wall w/ foam sheathing



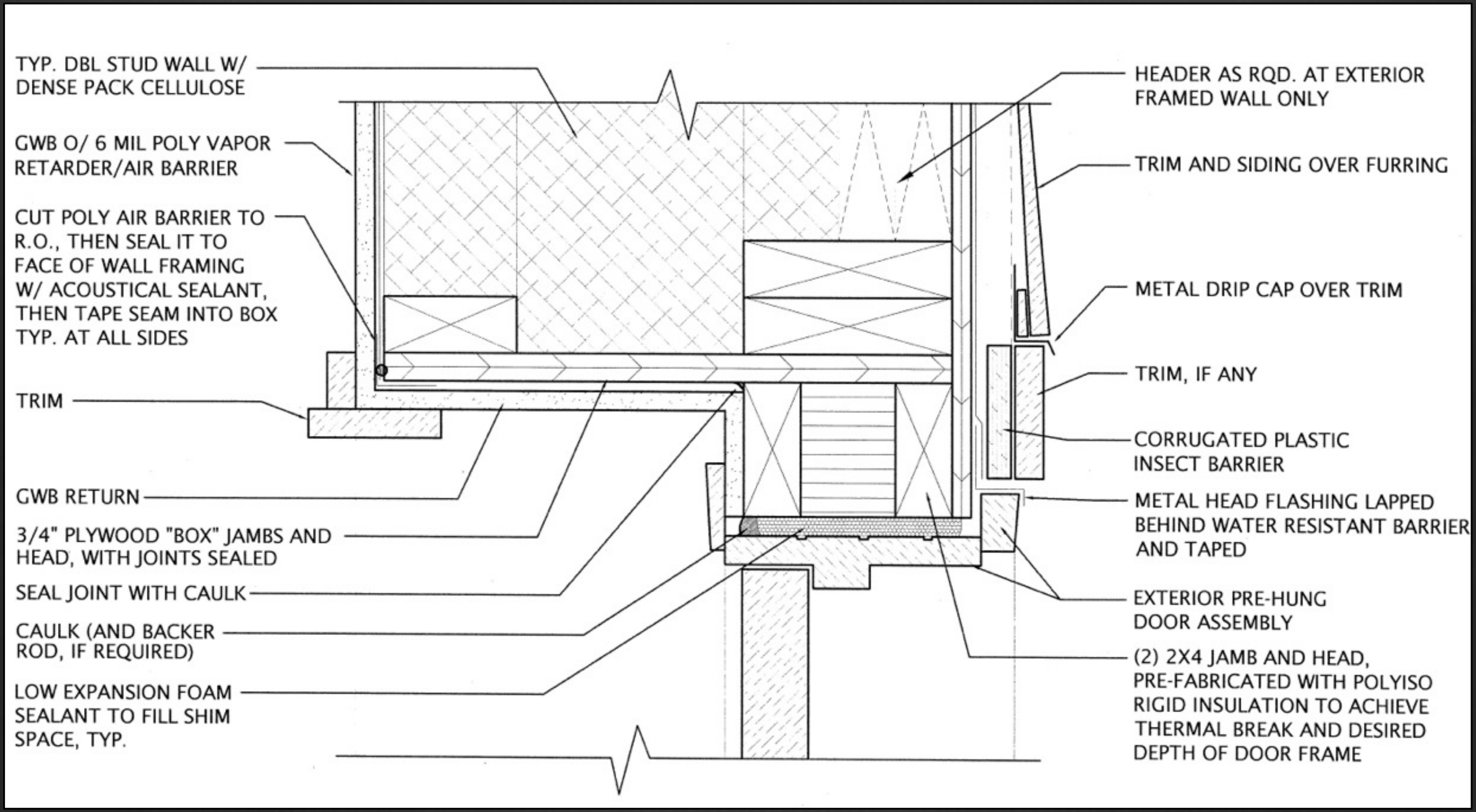

# Window inset in wall places window into a thermally preferable place



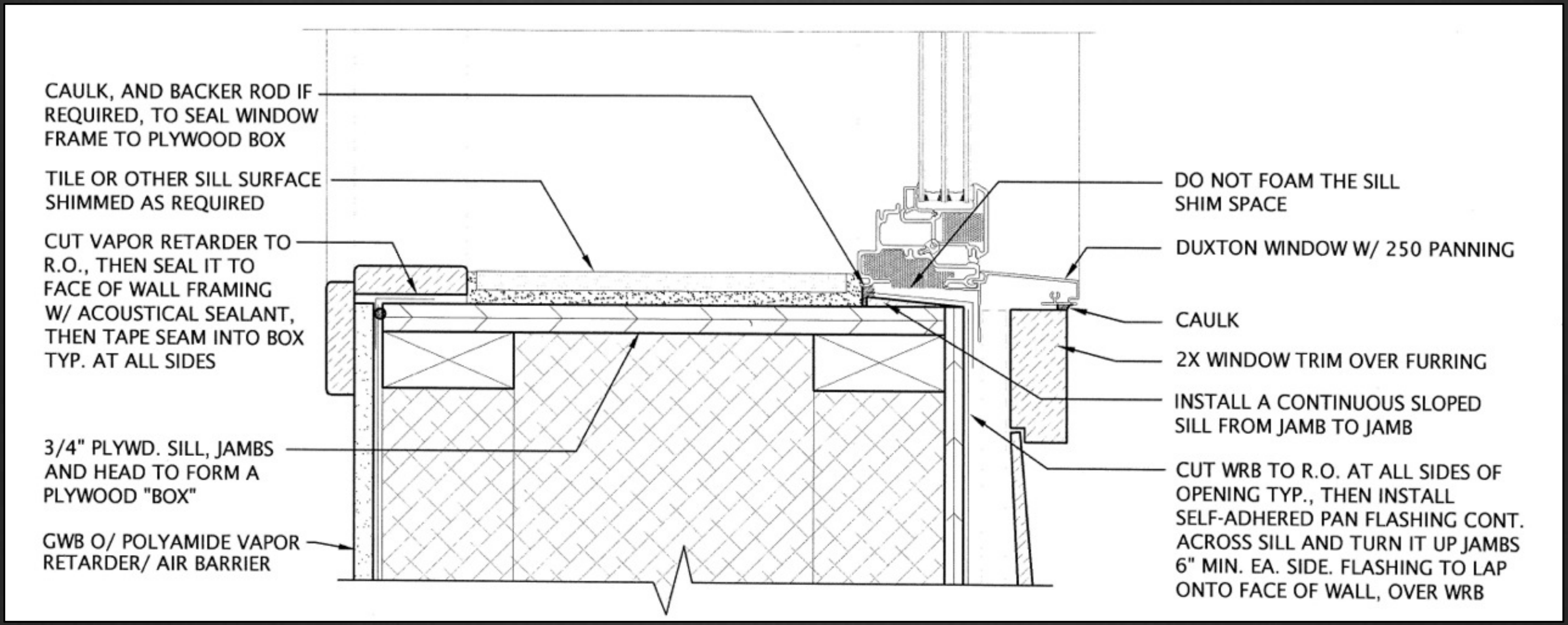

BUT such details make assembly more complicated, costly, and potentially more prone to installation error, water intrusion and harder to replace windows.

# Windows and Doors
# Part of the air barrier assembly
# so they need solid, continuous connection

# Details and installation require care



# Water management is critical in assembly design and installation



# Layer the assembly so water stays out and drains down

# The Roof

Functions:

Protect structure

Shed water and snow

Can also:

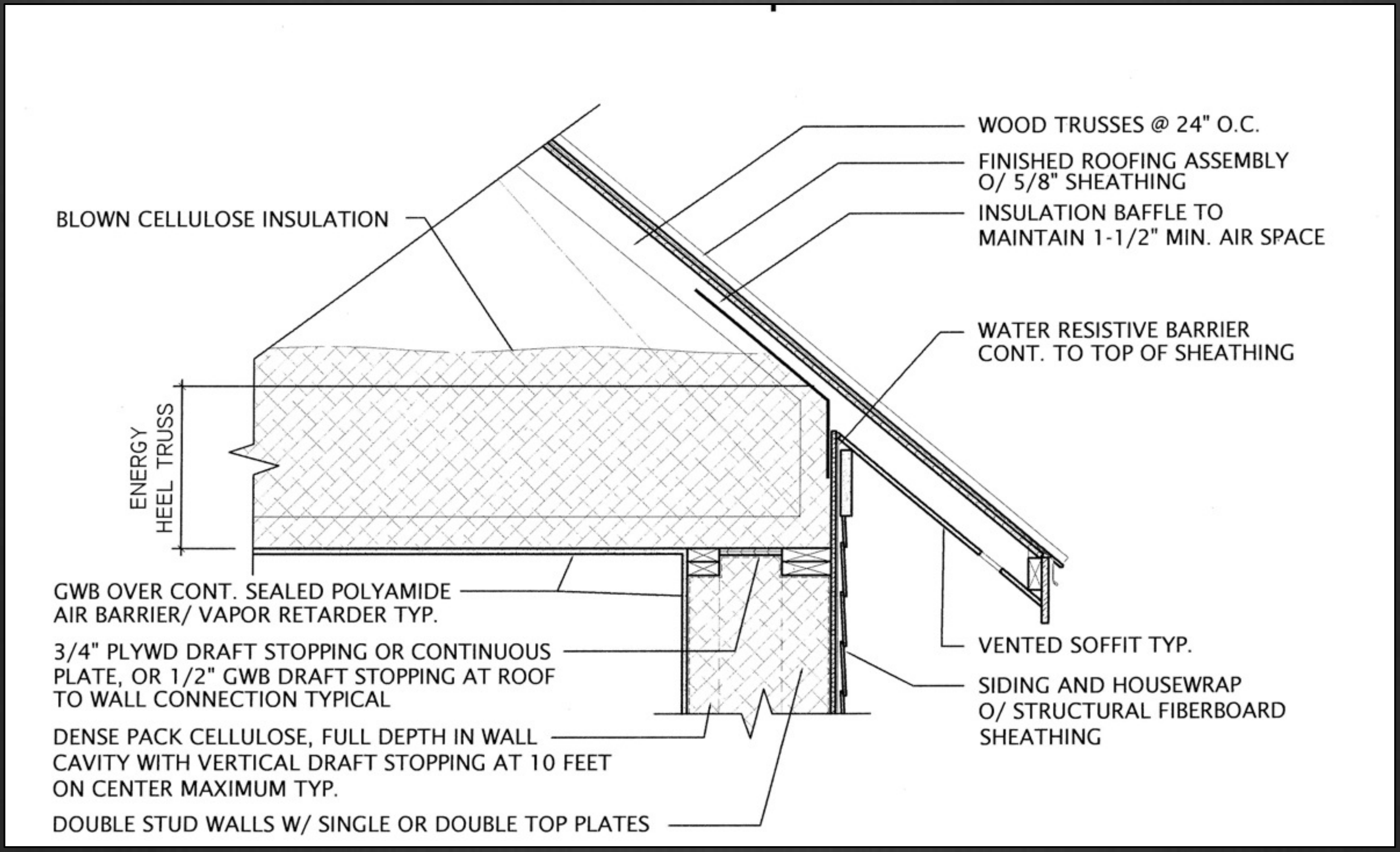
Divert rainwater

Manage solar gain

Create space

Hold equipment

# Truss heel makes super-insulation easy

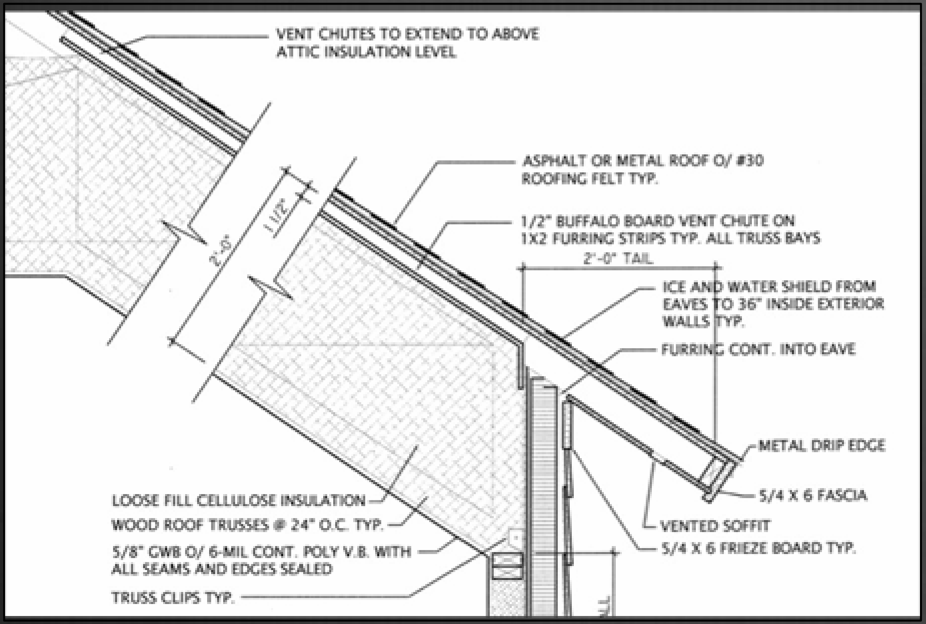



22” BLOWN CELLULOSE = R-80 ATTIC INSULATION

2009 and 2012 IECC requires R-49 in Climate Zone 7

# Managing Air in Roof Assemblies

- If roof is vented, control the path of ventilation from soffit to ridge.
- Be clear about connecting the air barrier.
- In cold climates, a vented roof is the safer path.




I like cellulose insulation, but cellulose should be in a vented roof assembly.
If moisture gets in, it can dry out.

# A super-insulated vaulted ceiling

- Frame with roof trusses to minimize thermal bridging
- To vent a vaulted ceiling: use site-built vent chutes to create air space and contain the insulation

# Seal Penetrations to the Air Barrier

Solid connections at penetrations maintain the air barrier.

If poly or other membrane is your air barrier at the ceiling (or wall), know what it can and cannot be easily sealed to in order to maintain the air barrier.

# Mechanical, Electrical and Plumbing (MEP) Systems

# Cold Climate Mechanical Matters

1. Little or no cooling load, but humidity can be an issue.
2. ASHP may not be suitable as sole heating device.
3. Combustion space heat is popular.
4. HPWH not always appropriate.

# Some MEP Guidelines

- Recognize that mechanical equipment is replaced more often than envelope elements – choose accordingly.
- Things will change over time – build in adaptability and accessibility to equipment and distribution systems.
- Build in good natural ventilation systems.
- Consider and optimize passive solar heating.
- Plan for redundancy and/or flexibility in heating systems.
- Make things understandable to the homeowner!

# Right sized space conditioning

- In a very low energy house, heat or cooling likely doesn't need to be delivered to every room, but comfort matters.
- Discussions with client and mechanical specialist can help guide decisions about heating and cooling equipment and distribution.

# The Reality of HVAC

Range hood, make up air unit, and wood stove.
House tested 0.7 ACH50. Stove doesn't backdraft.

# Why I like floor trusses

(but subs should cooperate or things can get ugly)

# High Performance, Low Energy in the Field

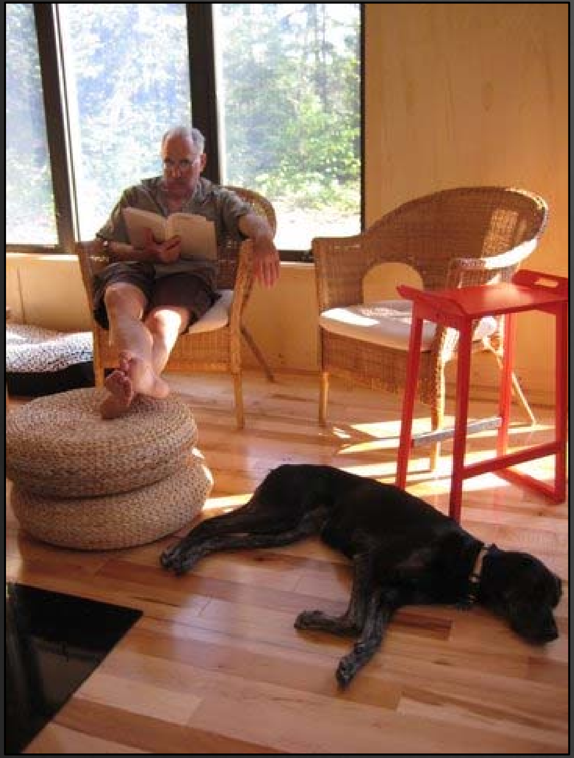
Gets “twice the mileage” or better than the average living vehicle

Can run on more than one fuel

Comfortable

Durable

# Real Benefits

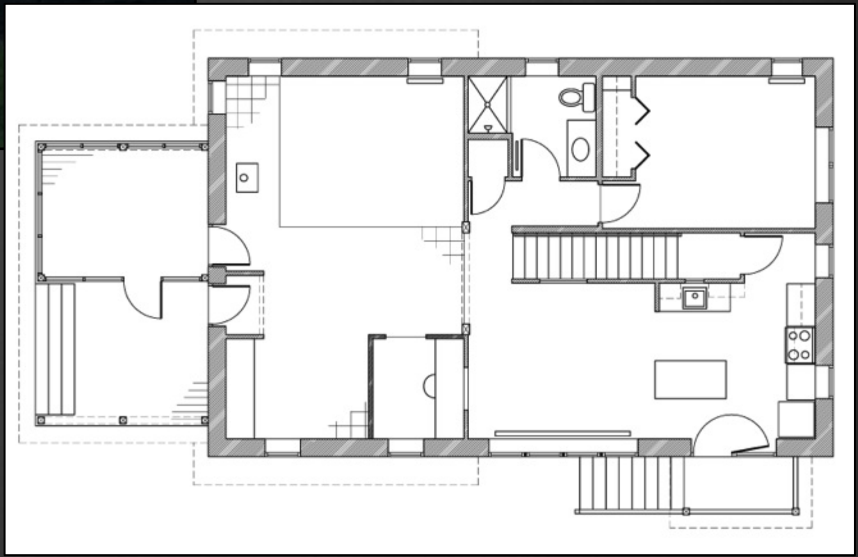


Comfort and Joy

# Esko House

Built 2009 (3 occupants)
3150 ft2
0.4 ACH50

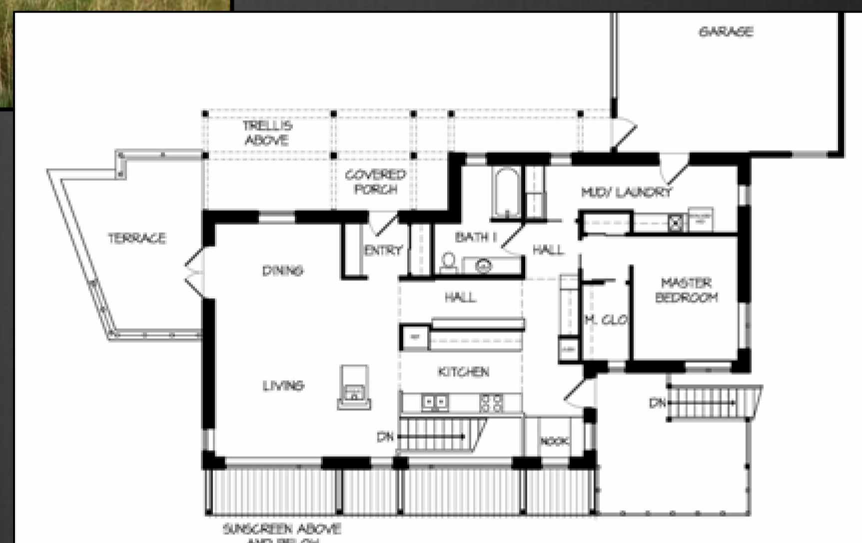
Heating Demand 20.5 MMBtu/yr
(4.87 kBtu/ft2/yr)



Total energy use average:
44.3 MMBtu/yr
(14 kBtu/ft2 ann)

# Skyline House

Built 2008 (4 occupants)
2950 ft2
0.7 ACH50




Heating Demand 19.4 MMBtu/yr
(6.58 kBtu/ft2 yr)

Total energy use 2009:
38.9 MMBtu/yr
(13.2 kBtu/ft2/yr)

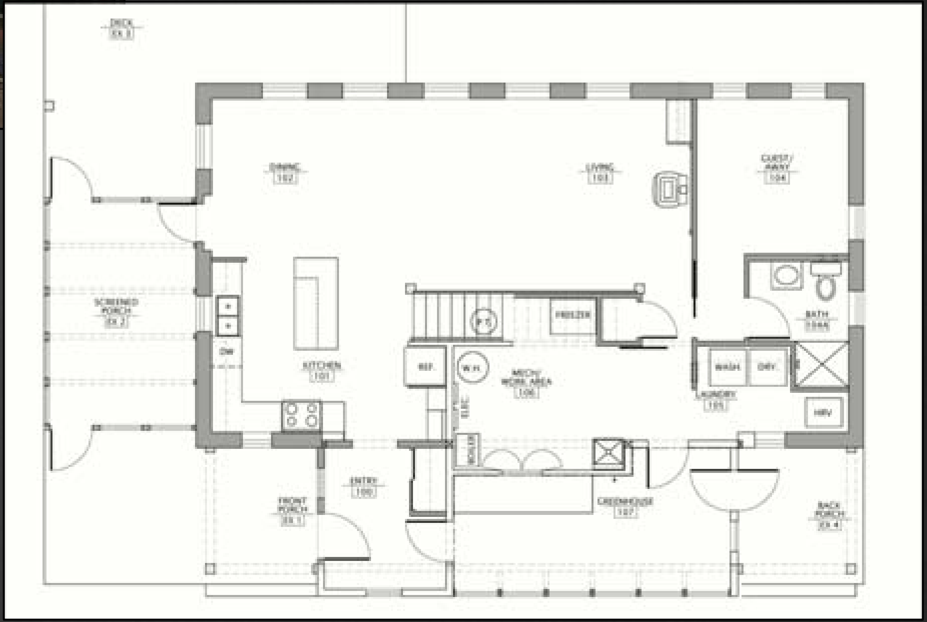
# Ecologists' House

Built 2014 (3 occupants)
2336ft2
0.83 ACH50

LIKELY NET ZERO
With 6.6 kW PV

Heating Demand unknown

Total energy use 2014-15:
22.3 MMBtu/yr (6454 kWh)
(9.5 kBtu/ft2/yr or 2.8 kWh/ft2/yr)
Total energy produced: 6389 kWh



# Seeing the Forest for the Trees

www.greenbuildingadvisor.com/blogs/dept/guest-blogs/best-practices-zero-net-energy-buildings
- Marc Rosenbaum, 2015

www.greenbuildingadvisor.com/blogs/dept/musings/martin-s-pretty-good-house-manifesto
- Martin Holladay, 2014

*Thank you.*

Wagner Zaun
ARCHITECTURE

17 N Lake Avenue
Duluth, MN 55802

218.733.0690
www.wagnerzaun.com