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From Control Layers to Robust, High-Performance Enclosures

For: Energy Design Conference

Date: February 23, 2022

By: Patrick Huelman, Associate Extension Professor
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University of Minnesota

IMPROVE EFFICIENCY, ENHANCE DURABILITY, AND REDUCE RISK WITH CONTINUOUS EXTERIOR INSULATION

- Part 1: Why => It's All About the Control Layers
- Part 2: What => High-Performance Enclosure Systems
- Part 3: How => Wall Case Studies

=> Using building science to guide us towards more robust, high-performance enclosure systems!

OVERARCHING THEMES

- We must challenge ourselves to achieve higher-performing buildings and enclosures that are efficient, durable, healthy, robust, and resilient!

- Existing technology can get us there, but …
  - We need to reduce the focus on finding the perfect product.
  - We must embrace more robust approaches and systems.
  - We need major improvements in design & execution.

OPENING QUESTIONS

- Are we putting our “eggs in a fragile basket”?

- Are we being realistic about the process?
  - Are we using risky designs, systems, and materials and hoping for perfect execution?
  - Are we counting on perfect homeowner operation and maintenance?

INTRO: MAKING THE CASE FOR ROBUST

- What must we do to move away from fragile …
  - Designs,
  - Systems,
  - Materials,
  - Methods, and
  - Operation?

MAKING THE CASE FOR ROBUST

- Fragile
  - Easily broken; not having a strong structure
  - Unlikely to withstand severe stresses and strains

=> Things that make perfect sense on paper, but seem to be “too fragile” to handle the real life situations they encounter.

MAKING THE CASE FOR ROBUST

- Robust
  - Strong, healthy, and hardy in constitution
  - Built, constructed, or designed to be sturdy, durable, or hard-wearing
  - A system that is able to recover from unexpected conditions during operation

=> Things that seem to work regardless what your subs, clients, or nature throws at them!

MAKING THE CASE FOR ROBUST

- When push comes to shove; will your home's response be fragile or robust?
  - Execution errors
  - Unusual operations
  - Abnormal interior conditions
  - Neglected maintenance
  - Climate extremes

MAKING THE CASE FOR ROBUST

- This demands a new approach. We must …
  - design and engineer (not just build) our homes.
  - build forgiveness/tolerance into all systems.
  - build redundancy into critical elements and materials.
    - or make it easy to repair and/or replace key components
  - develop a more predictable delivery system.
  - provide continuous feedback to the occupant.

MAKING THE CASE FOR ROBUST

- Today we are going to focus on how to build high-performance building enclosures that are more robust and resilient!

- All within the context of critical labor, materials, and supply chain issues!

A QUICK BUILDING SCIENCE REVIEW

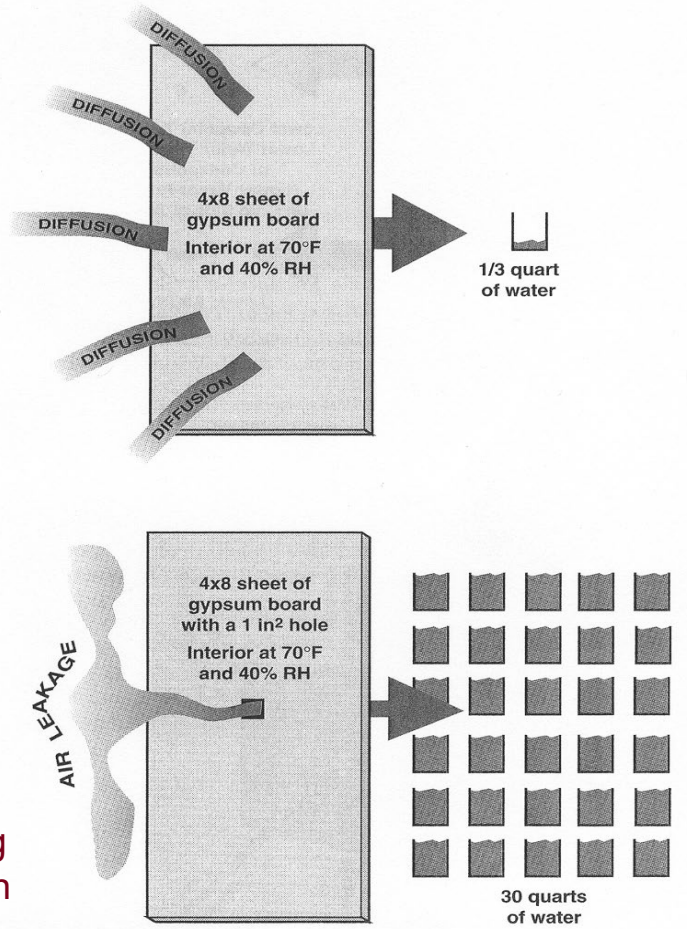
- Remember -- it really boils down to three things!
  - Heat Flow
  - Air Flow
  - Moisture Flow

BUILDING SCIENCE CHEAT SHEET

- Heat always flows from hot to cold
- Moisture goes from more to less
- Cooling is wetting; heating is drying
- Airflow requires and path and a pressure
- Air can carry significant heat and moisture
- Vapor diffusion is a very slow process
- Bulk water and capillarity are powerful wetting mechanisms
  - and will overwhelm highly insulated and airtight enclosures

MOSITURE TRANSPORT: VAPOR

- Airflow vs. Diffusion
  - Large or ongoing air flow in the wetting direction (from warm to cold) can be disastrous.
  - However, in the past wall airflow was also a significant drying mechanism.
  - If air flow is restricted, the only drying mechanism is diffusion.



Courtesy of Building Science Corporation

MOISTURE CONTROL: GENERAL

- Over some critical period, drying must exceed wetting!
- Material storage provides a buffer between wetting & drying.
  - Things get wet, so ample storage (buffer capacity) must be provided until drying can be completed.
    - concrete/masonry walls provide a lot of storage
    - steel frame and fiberglass provide almost no storage
    - wood framing and sheathing provide limited storage
- In tight assemblies, almost all drying is by vapor diffusion!

PART 1A. THE FOUR CONTROL LAYERS

- Every enclosure element must have four control layers!
  - Thermal control
  - Water control
  - Air control
  - Vapor control

THERMAL CONTROL LAYER(S)

- General Overview
  - The intent is to slow the transmission of heat moving from warm to cold.
    - primary driver is the temperature difference across the enclosure
    - flow rate will be determined by the overall U-value (or R-value)

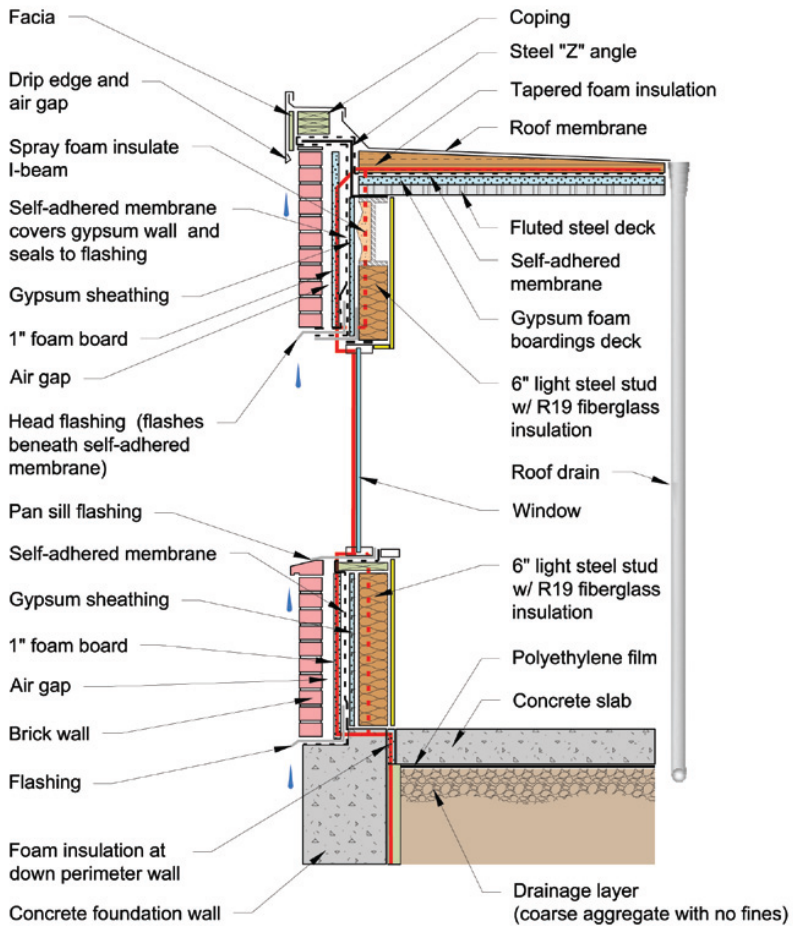
- In many ways, this is the easy one!
    - how much? where? what type?
    - minimizing major thermal breaks

PATHWAY TO ZERO: METRICS

Enclosure (R-values)	MN Code	ENERGY STAR	DOE ZERH	BCP (PH)	NZE Now (JL)*
Ceiling	49	50	50	50	60
Walls	20/21	25	25	30	40
Floors	30/38	30/38	30/38	40	--
Foundation	15(10)	15	15	15	20
Slabs					
- Basement	0	0	0	10	10
- On-grade	10	10	10	15	20

* From “BSI-081 Zeroing In” by Joseph Lstiburek

PEN TEST: RED LINE FOR INSULATION



WATER CONTROL LAYER(S)

- General Overview
  - The intent is to keep water from reaching any moisture susceptible layers.
    - primary drivers are gravity, wind, capillarity
    - drivers can (and should) be mitigated

- This is absolutely critical,
  - especially as we remove drying potential with increased insulation, reduced air flow, and multiple vapor retarders!

WATER CONTROL LAYER(S)

- Sources of Bulk (Free) Water
  - precipitation
  - groundwater
  - melting ice & snow
  - condensation
  - plumbing leak
  - spills & overflows

WATER CONTROL LAYER(S)

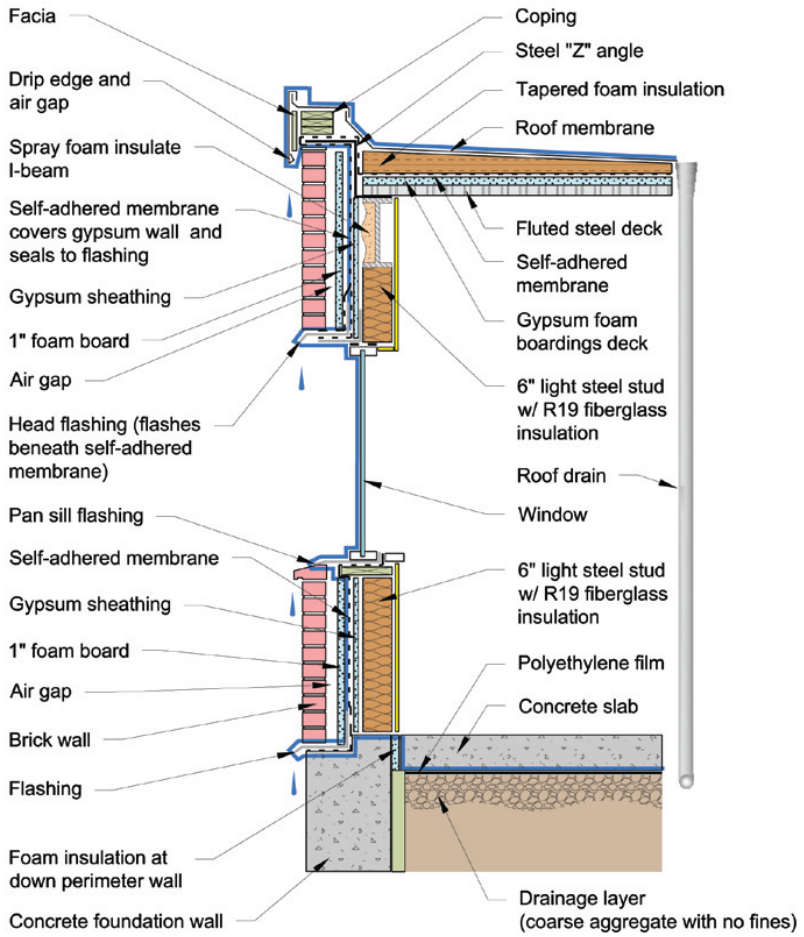
- Controlling bulk water is the single most important factor in the design and construction of durable and healthy buildings.

- The four Ds of water management
  - design
  - deflect
  - drain
  - dry

WATER CONTROL LAYER(S)

- Drain, drain, drain!!!
  - use gravity to shed rain, surface, and ground water down and out
- What can't be drained must have a robust back-up.
  - secondary water management layer
  - another method of water removal
  - safe material storage
- What get's stored must have a solid drying strategy.
  - sufficient energy to evaporate & vapor open in the drying direction

PEN TEST: BLUE LINE FOR WATER



AIR CONTROL LAYER(S)

- General Overview
  - The intent is to keep air from moving across the building enclosure carrying heat and moisture to locations that may create energy or moisture problems.
    - primary driver is air pressures
    - indoor air pressure can (and must) be managed
    - eliminating/minimizing holes is the key to success

- This is absolutely essential in modern construction.

AIR CONTROL LAYER(S)

- Framework for Airtightness
  - Material = 0.02 l/s-m^2 @75Pa
  - Assembly = 0.20 l/s-m^2 @75Pa
  - Building = 2.0 l/s-m^2 @75Pa

PATHWAY TO ZERO: METRICS

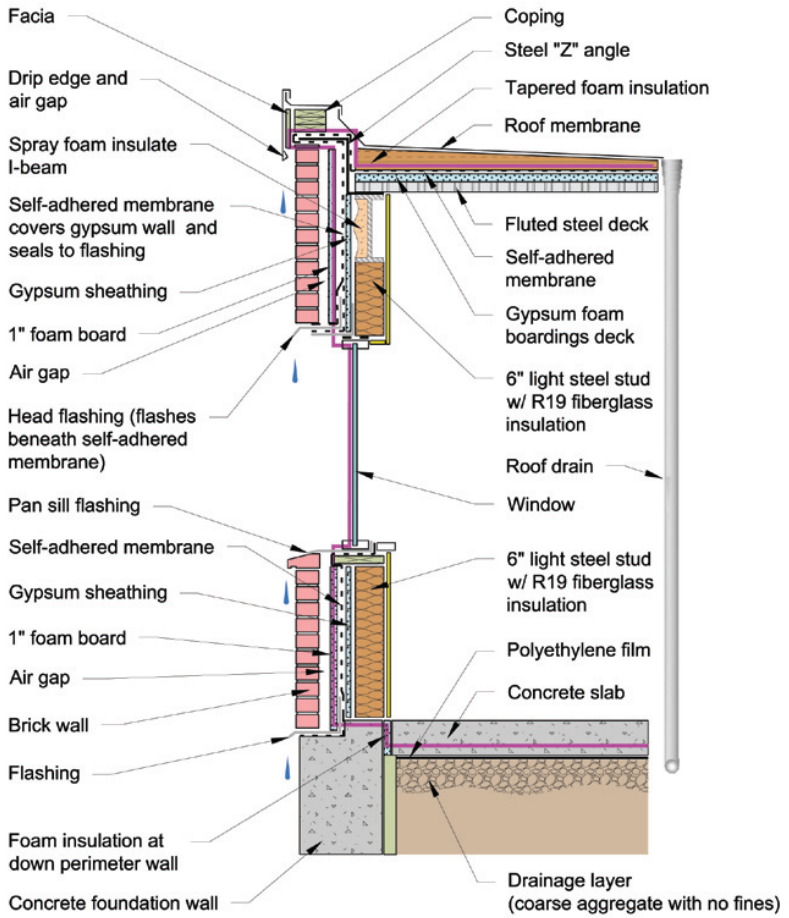
Enclosure Airtightness	MN Code	ENERGY STAR	DOE ZERH	BCP (PH)	NZE (JL)*
ACH@50Pa	3.0	3.0	2.0	1.0	1.5

* From “BSI-081 Zeroing In” by Joseph Lstiburek

AIR CONTROL LAYER(S)

- There are many things that can serve as an air barrier.
  - gasketed drywall, sealed poly or SVR, spray foam
  - taped sheathing, FAM & LAM, wrb/housewraps
- But where does it belong?
  - inside => traditional location for cold climates
  - outside => an ideal location in hot, humid climates
  - can both sides work => sure
  - how about in the middle => absolutely
- But remember, in the end it is all about continuity!

PEN TEST: PURPLE LINE FOR AIR



VAPOR CONTROL LAYER(S)

- General Overview
  - The intent is to control vapor diffusion across a vapor pressure or thermal gradient.
    - primary driver is the vapor pressure difference
    - indoor vapor pressure can (and should) be managed
    - flow rate will be determined by material permeability
- While it might not seem as critical, it can't be ignored in …
    - very cold climates
    - hot humid climates
    - high humidity environments

VAPOR CONTROL LAYER(S)

- General Overview (continued)
  - In general, as thermal insulation increases the vapor permeance across the insulation must decrease.
  - Today (due to air-conditioning) you must manage vapor from both directions.
  - But remember -- almost all drying occurs by vapor diffusion.
  - So if anything gets wet there must be a clear drying direction.

VAPOR CONTROL LAYER(S)

- Framework for Material Permeability
  - Class 1 = < 0.1 perm impermeable
  - Class 2 = 0.1 to 1.0 perm semi-impermeable
  - Class 3 = 1.0 to 10 perm semi-permeable
  - Class 4 = > 10 perm permeable

VAPOR CONTROL LAYER(S)

- In colder climates, the building code has required a Class 1 or 2 vapor retarder for some time.
  - 1 perm or less on the warm side in winter
  - now there are exceptions with continuous exterior insulation
- The current codes don't address exterior vapor retarders for summer conditions.
  - but inward vapor pressure is real depending on cladding choices
  - best practice would suggest you design for inward vapor protection

VAPOR CONTROL LAYER(S)

- 1 perm (Class 2) is an interesting, but not lonely number!
  - ½” OSB (dry cup)
  - smart vapor retarder (dry cup)
  - 1” extruded polystyrene
  - kraft-faced paper
  - several coats of oil-based paint

VAPOR CONTROL LAYER(S)

- 0.1 perm can be a tricky number!
  - Generally this is lower than needed to prevent wetting and it will significantly shut down drying.
  - However, it can be safe, if it is used in the right location.
  - In the end, a Class 1 vapor retarder surface must be warm enough to prevent condensation in both summer and winter.

VAPOR CONTROL LAYER(S)

- Vapor control is more of a strategy than a specific layer.
- However, there are a couple of questions that can guide the enclosure design.
  - Does the assembly have a hard condensing plane that may be cold enough to induce condensation in winter or summer?
  - Is there a sufficient vapor throttle to prevent vapor wetting of moisture susceptible materials from inside out and/or outside in?
  - Is there a clear drying direction along with sufficient energy to dry out any moisture susceptible materials?

THE MODERN ENCLOSURE CONUNDRUM

- We spent several decades focused on energy efficiency without concurrent attention to moisture management!
- Initially we focused on management of condensation due to vapor diffusion.
- Later it was recognized that air leakage was a far bigger moisture risk and we began to address air barriers.
- Then it became painfully apparent that we weren't paying sufficient attention to the management of bulk water.

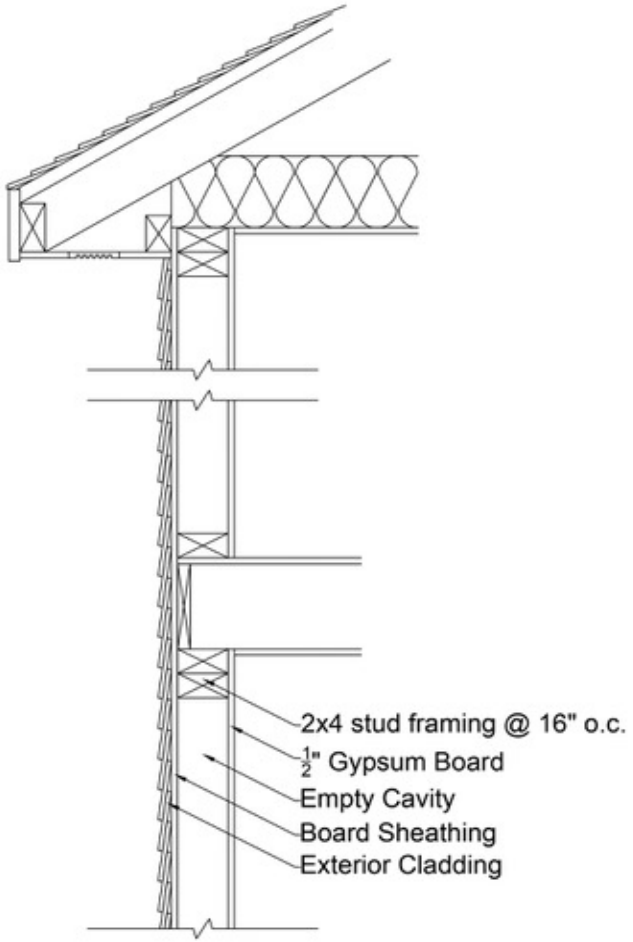
THE MODERN ENCLOSURE CONUNDRUM

- However, only recently has the conversation turned to the importance of maintaining a drying potential
  - We recognize that things can get wet at some point due to imperfect design, execution, or operation.
  - Therefore, all moisture susceptible materials must be able to dry out primarily by vapor diffusion
    - that can be outward in winter; inward in summer,
    - except below grade, which can only dry inward.

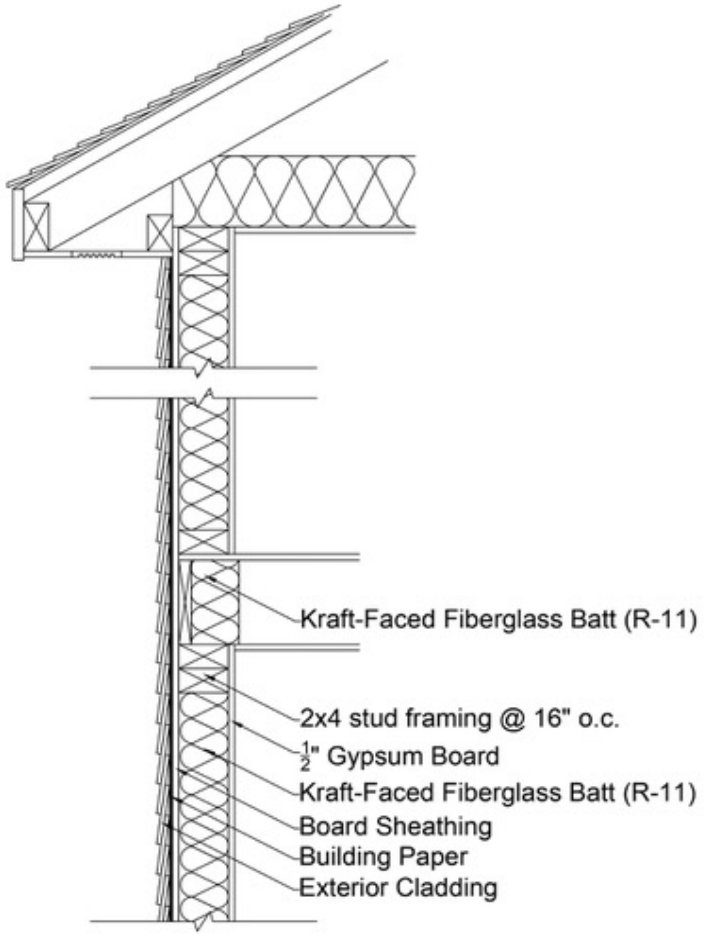
SO LET'S REVIEW HOW WE GOT HERE!

- Where were we?
- Where are we?
- Where do we need to go?

Wall A: Older, Uninsulated Frame Wall



- Energy performance is very poor
  - especially in cold and hot climates
- Moisture is managed by substantial heat and air flows
  - wetting potential is high, but so is the drying potential
- Poor comfort due to drafts and cold/hot interior surface temperatures
- ***It may be durable, but it is unacceptably inefficient and uncomfortable!***



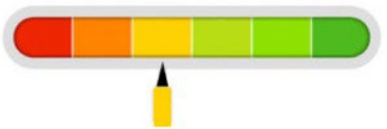
Wall B: Older, Insulated Frame Wall

- Improved thermal efficiency
- Wetting potential goes up due to possible condensation; water intrusion potential remains
- Drying potential is reduced as a result of less heat transfer and less permeable layers/linings
- Improved surface temperature, but may still be drafty
- ***More efficient and comfortable, but not as durable or robust!***

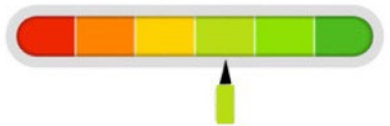
Energy

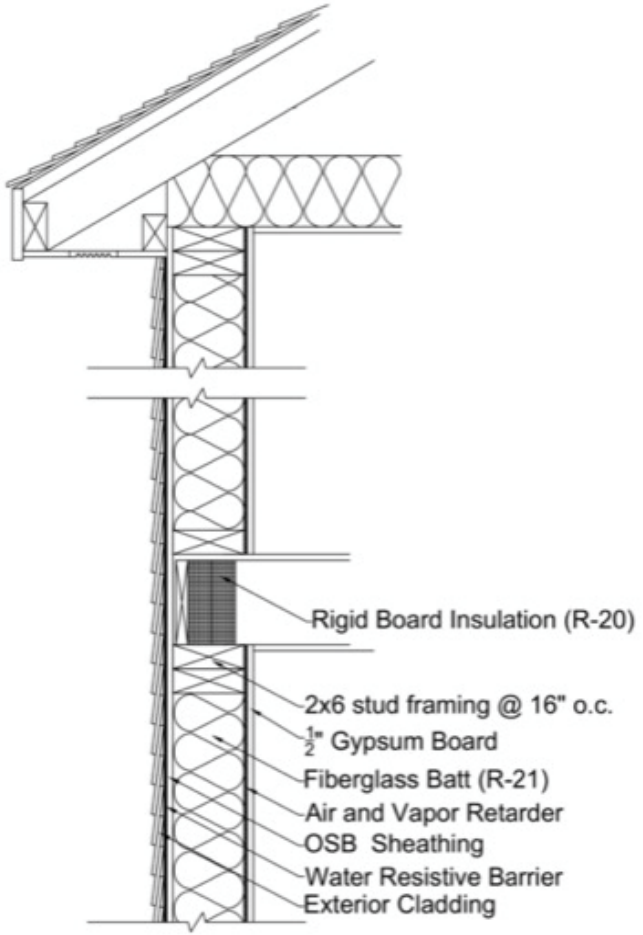
Wetting Potential

Drying Potential



Comfort

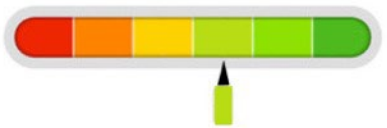




Wall C: Typical Frame Wall

- Improved thermal and air control for higher energy efficiency
- With excellent craftsmanship all wetting mechanisms can be reduced
- However, drying potential is extremely limited
  - a bulk water leak or localized condensation could be disastrous
- High level of occupant comfort
- ***Very efficient and comfortable, but potentially risky and not very robust!***

Energy

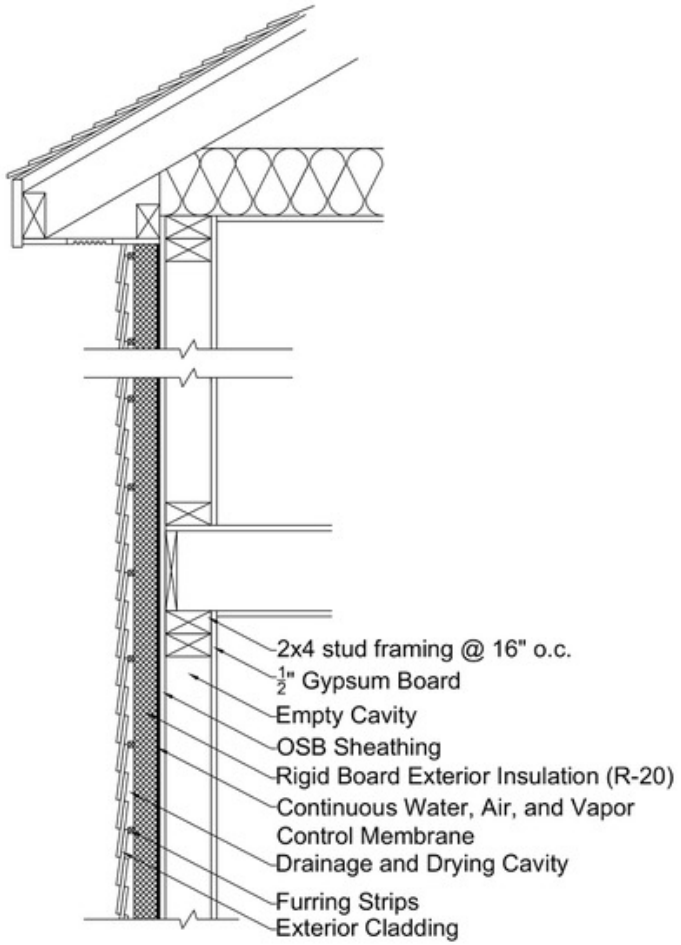


Wetting Potential

Drying Potential

Comfort

Wall D: "Perfect Wall" w/ CEI



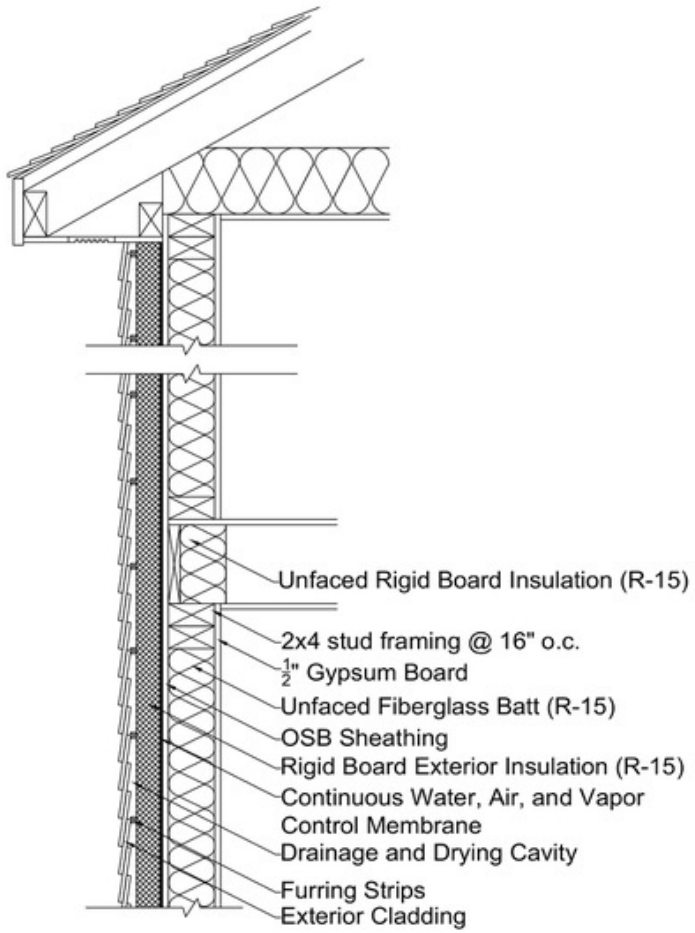
- Improved thermal and air control for higher energy efficiency
- All moisture transport mechanisms can be easily addressed to reduce the wetting potential
- Excellent ability to dry in both directions
- High level of occupant comfort
- Works in all climates (R-values can be adjusted to suit)
- Flexible framing, electrical, and interior finishes
- ***Very durable, efficient, comfortable, and robust!***

Energy

Wetting Potential

Drying Potential

Comfort



Wall E: Hybrid Wall w/ CEI

- Outstanding energy performance
- All moisture transport mechanisms can be easily addressed to reduce the wetting potential
- Maintains ability to dry in both directions
- Very high level of occupant comfort
- Works for all climate zones
  - R-values and ratios can be adjusted to fit
- Flexible framing, electrical, and interior finishes
- ***Extremely efficient, comfortable, durable and robust!***

Energy

Wetting Potential

Drying Potential

Comfort

TIME FOR A QUICK PAUSE

- Questions
- Thoughts
- Reflections
- Discussion

PART 2A. DEVELOPING A FORGIVING ENCLOSURE

- The building enclosure is the separator between the indoor and outdoor environments.

- In an enclosure system, as the energy flow goes down the moisture risk goes up!
  - Less energy means colder materials and surfaces
  - Colder means higher RH and increases wetting potential
  - If something gets wet, it takes significant energy and a drying potential to remove the moisture.

DEVELOPING A FORGIVING ENCLOSURE

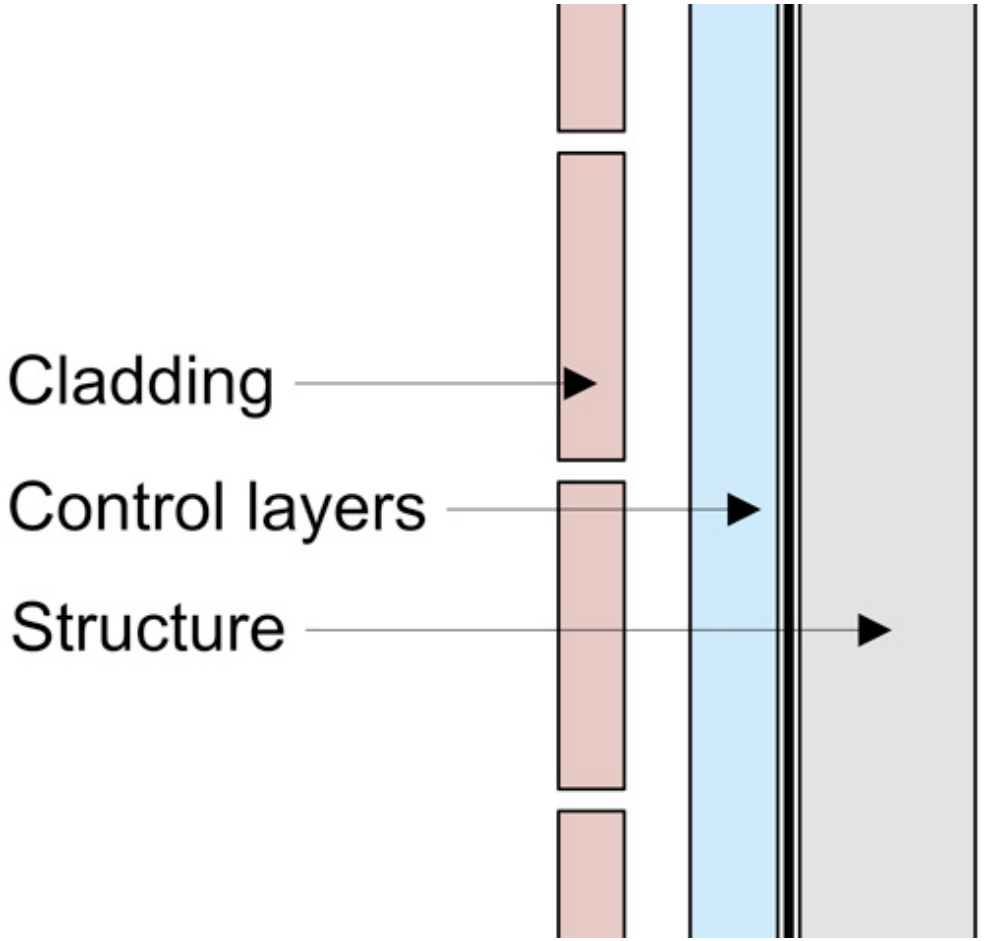
- The “Perfect” Strategy for:
  - Walls
  - Roof
  - Slab
  - Foundation

- Move the structure to the inside and the control layers to the outside …
  - It simply works and works everywhere!!!

DEVELOPING A FORGIVING ENCLOSURE

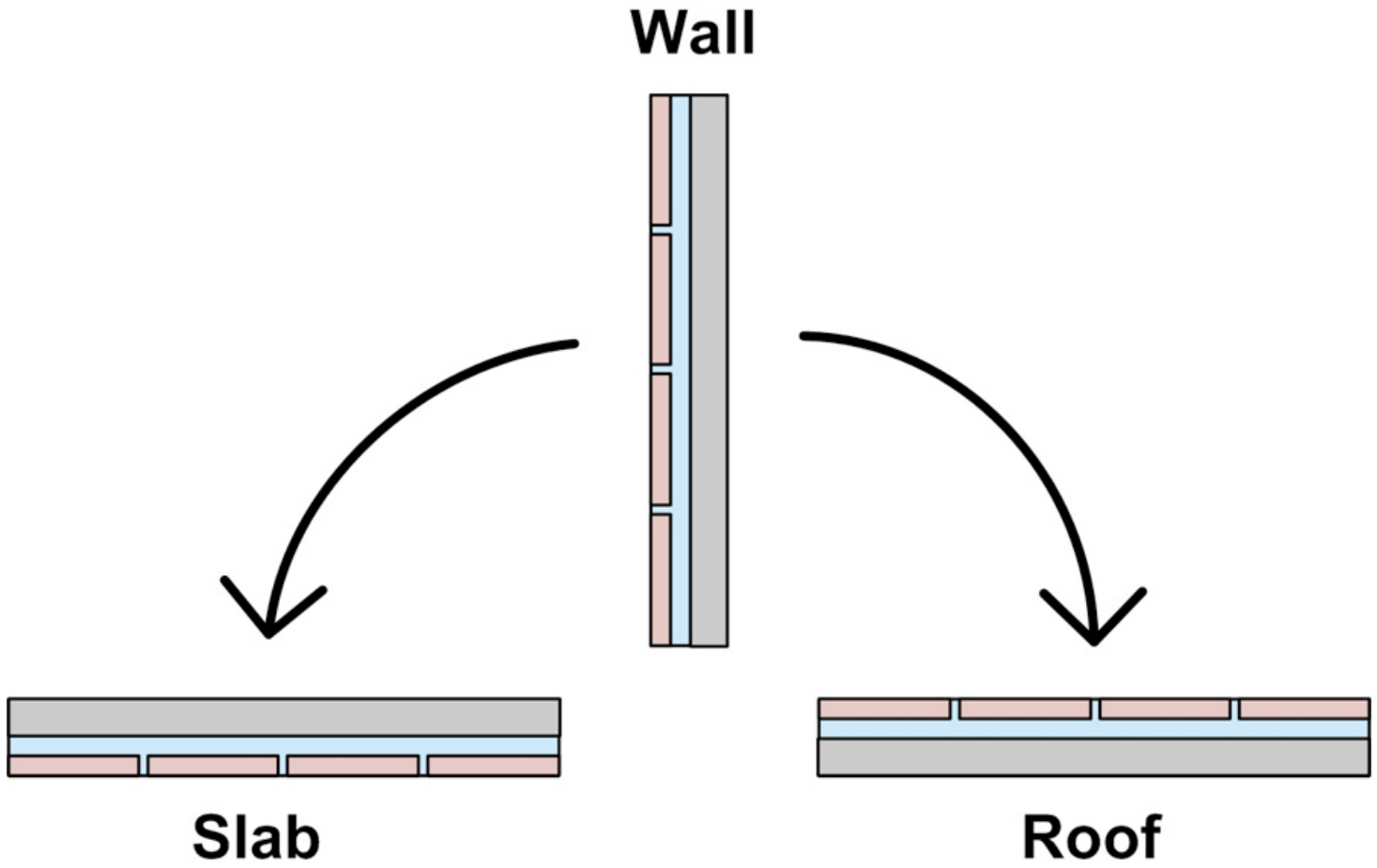
- While the name may change, the concept stays the same!
  - Perfect Wall (Joe Lstiburek w/ credit to Canadians)
  - PERSIST (Canadians)
  - REMOTE (Alaskans)
  - PERFORM (Texans)
  - Out-sulation (industry)
  - Exterior Thermal & Moisture Management System (CCH)
  - Continuous Exterior Insulation (industry & codes)

THE PERFECT WALL (FROM BSC)

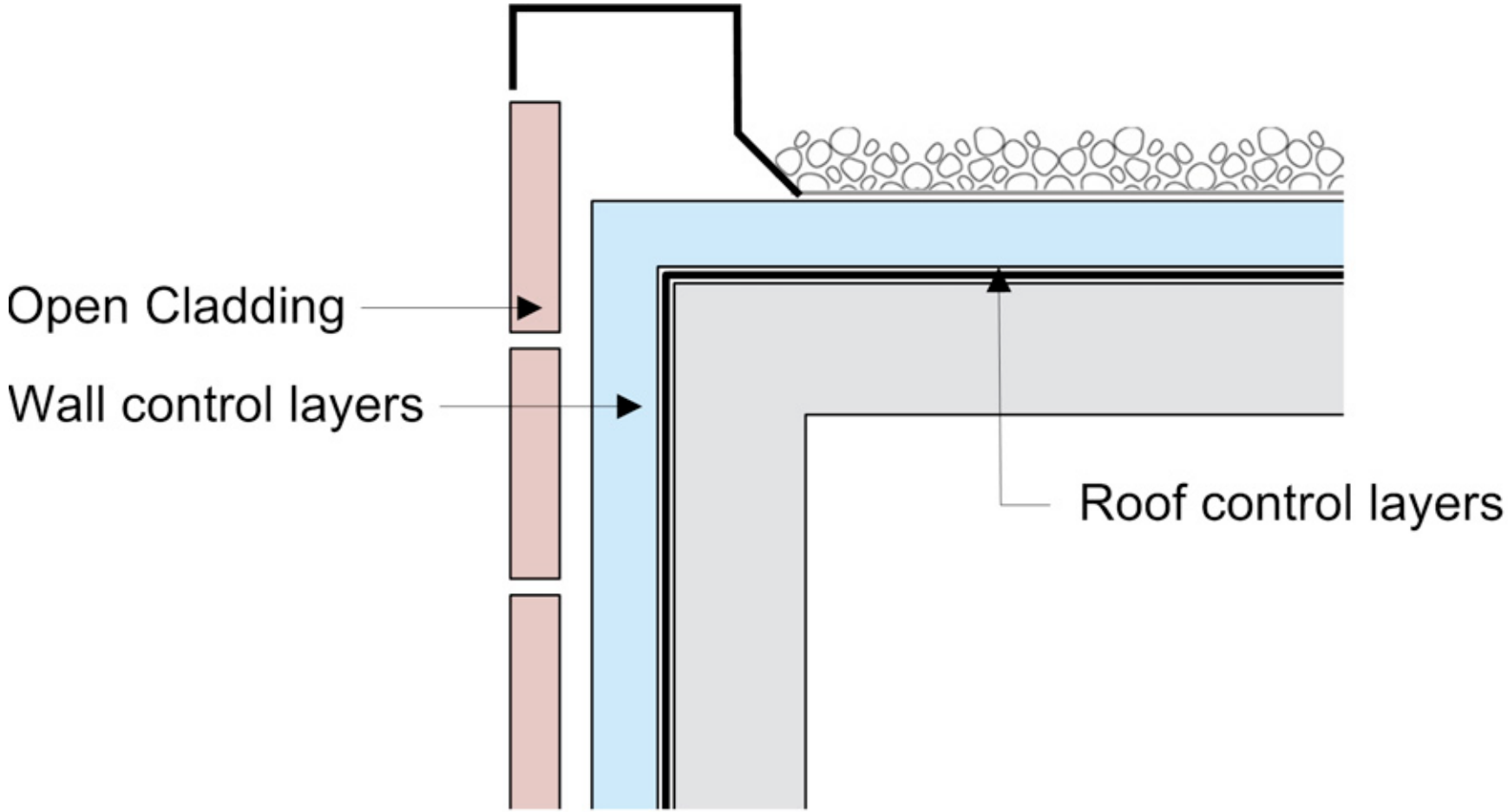


* BSI-001: The Perfect Wall
Joseph Lstiburek
Building Science Corporation

WORKS FOR ROOF & SLAB, TOO!



PERFECT CONNECTIONS

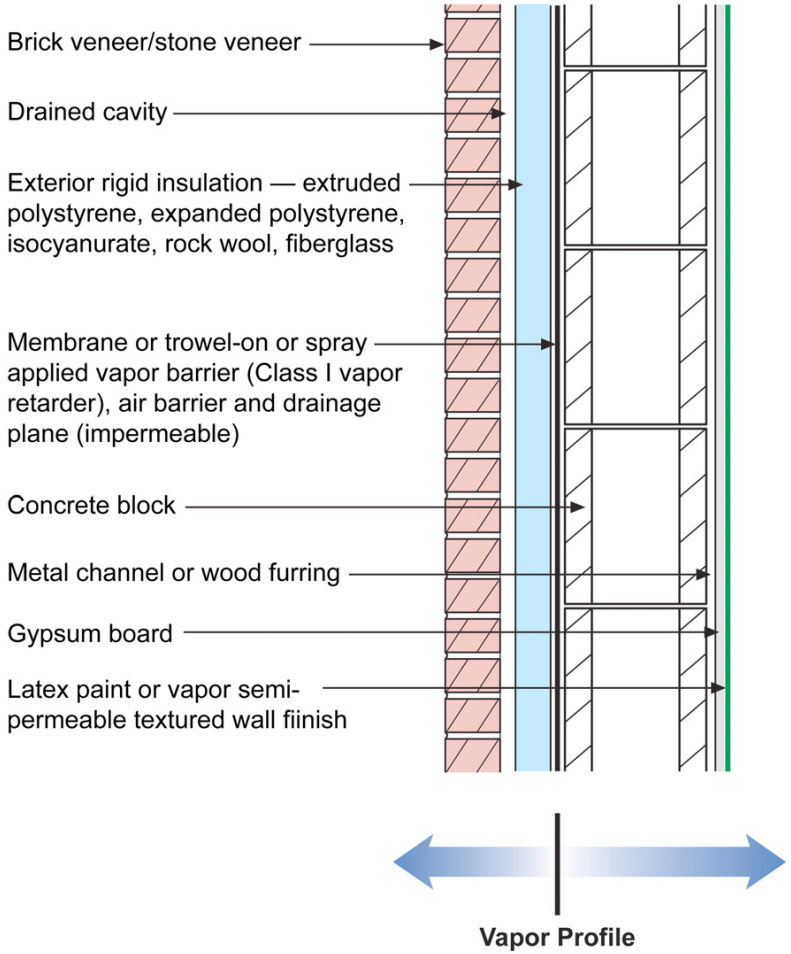


PUTTING THE LAYERS TOGETHER

- Back to the Control Layers
  - Thermal
  - Water
  - Air
  - Vapor

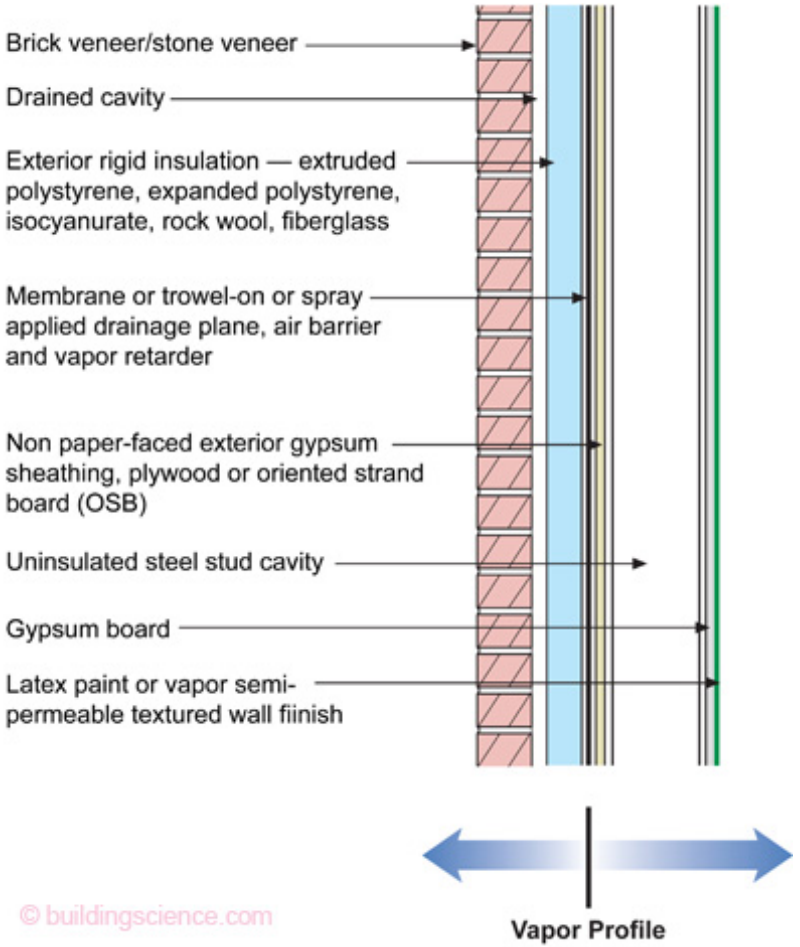
- What you use is important, but the where, how, and when (order/sequence) is critical.
  - However, it can be extremely simple!

THE PERFECT INSTITUTIONAL WALL



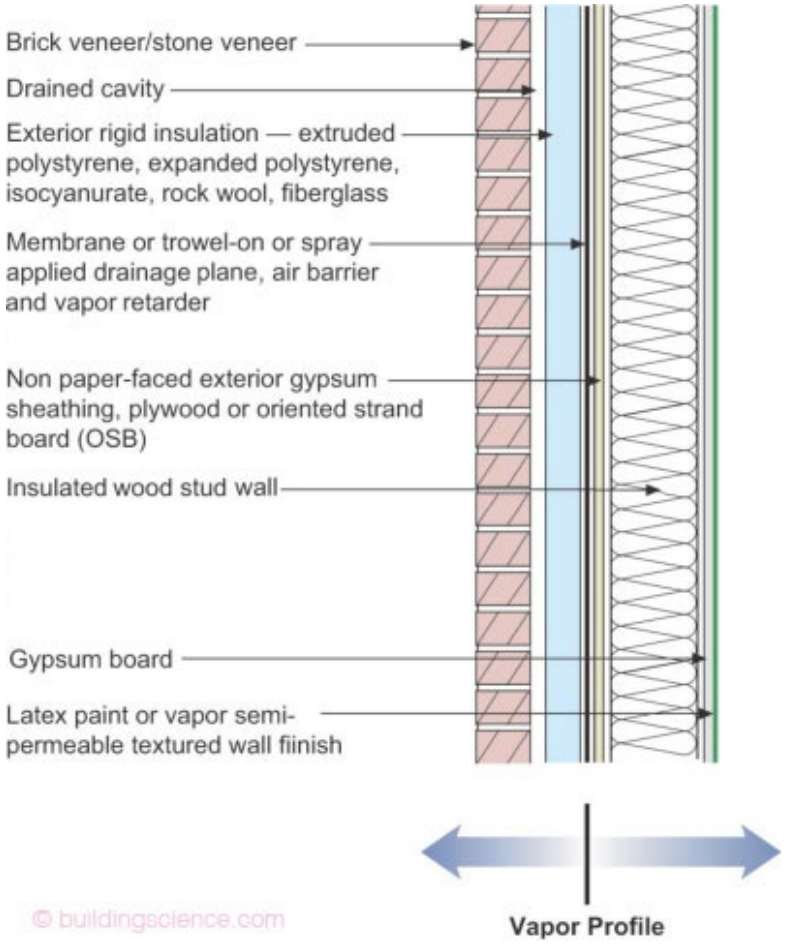
Courtesy of Building Science Corporation

THE PERFECT COMMERCIAL WALL



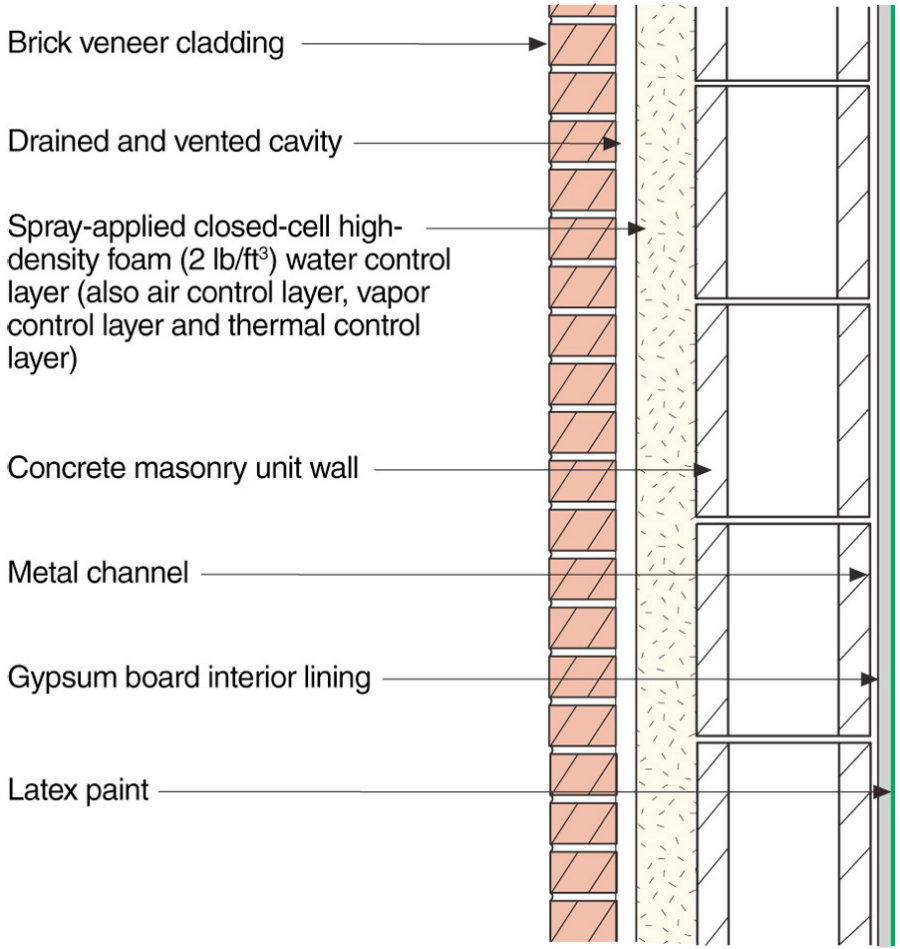
Courtesy of Building Science Corporation

THE PERFECT RESIDENTIAL WALL



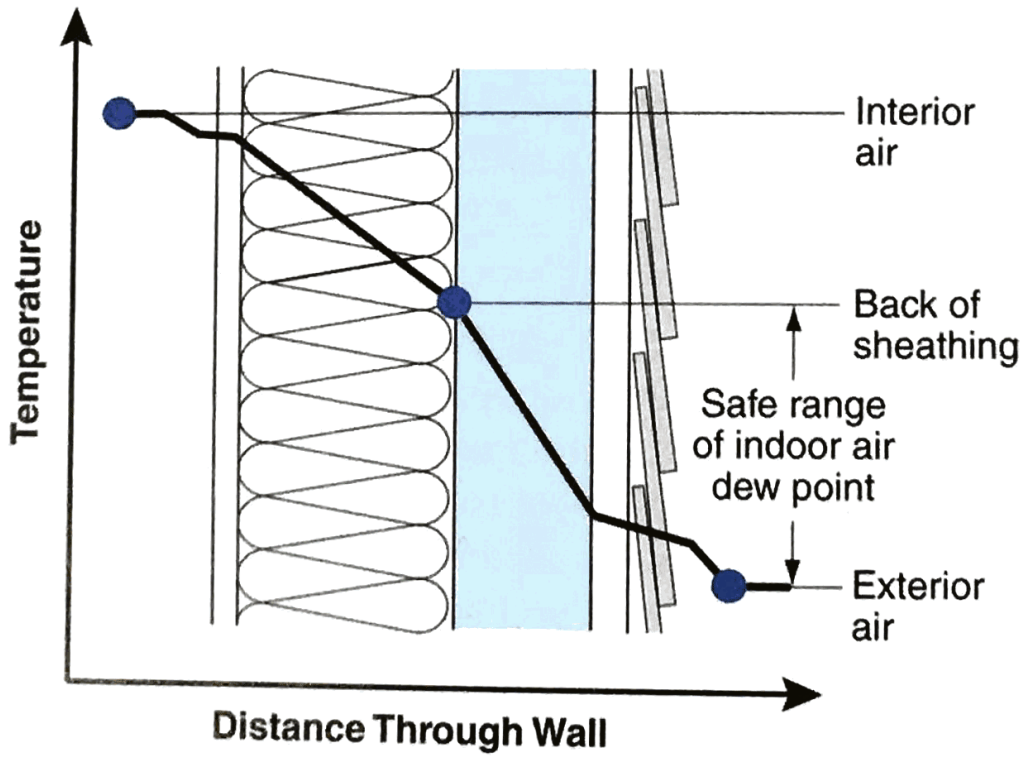
Courtesy of Building Science Corporation

4 IN 1 CONTROL LAYER



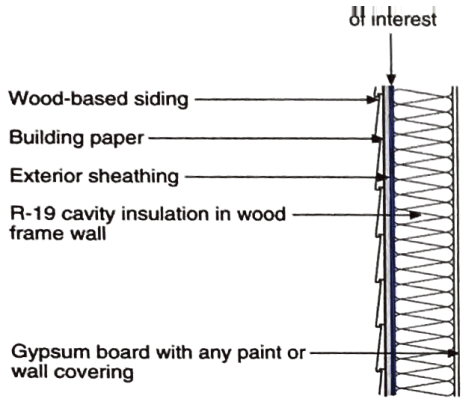
HOW MUCH EXTERIOR INSULATION?

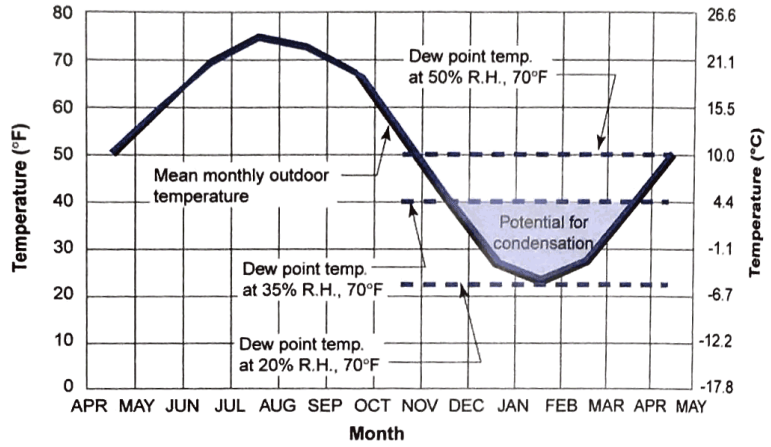
$$T_{back\ of\ sheathing} = T_{interior} - (T_{interior} - T_{exterior}) \frac{R_{batt}}{R_{total}}$$

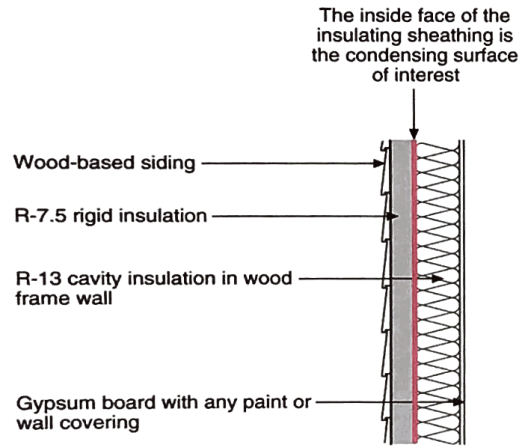


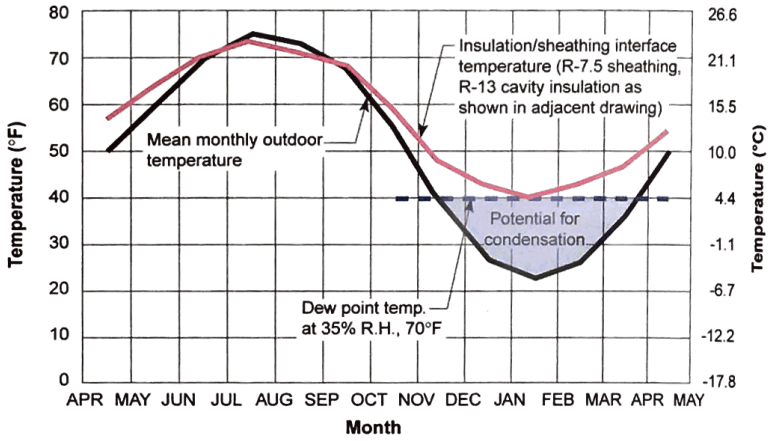
High Performance Enclosures:
John Straube, 2012

CONDENSATION POTENTIAL









High Performance Enclosures: John Straube, 2012

% OF EXTERIOR INSULATION

Indoor		RH	20	25	30	35	40	50	60
Dew point		°C	-3.0	0.0	2.5	4.7	6.6	9.9	12.7
		°F	26.6	32.0	36.6	40.5	44.0	49.9	54.8
$T_{outdoor}$	°C	°F							
	0	32	0.00	0.00	0.12	0.23	0.32	0.47	0.60
	-5	23	0.08	0.19	0.29	0.37	0.45	0.57	0.68
	-10	14	0.23	0.32	0.40	0.48	0.54	0.64	0.73
	-15	5	0.33	0.42	0.49	0.55	0.60	0.69	0.77
	-20	-4	0.41	0.49	0.55	0.60	0.65	0.73	0.80
	-25	-13	0.48	0.54	0.60	0.65	0.69	0.76	0.82
	-30	-22	0.53	0.59	0.64	0.68	0.72	0.78	0.84
	-35	-31	0.57	0.63	0.67	0.71	0.74	0.80	0.85
	-40	-40	0.61	0.66	0.70	0.73	0.76	0.82	0.86

High Performance Enclosures: John Straube, 2012

PART 2B. ROBUST BUILDING ENCLOSURES

- Continuous exterior insulation improves efficiency, enhances durability, adds robustness, and reduces risk!
  - Below grade slabs and walls are a top priority due to increased wetting potential and limited drying potential to the exterior
  - Above grade walls are the next priority due to bulk water concerns and dual (winter & summer) vapor wetting potential
  - For flat or slope roof/ceiling configurations it should be given heavy consideration
    - However, it is less important on traditional roofs due to better water management and forgiveness provided by attic venting.

FOUNDATION MOISTURE CHALLENGES

- Foundations get wet from four sides by all four moisture transport mechanisms.
  - bulk water, capillarity, diffusion, and air flow
- Foundations must dry primarily to the inside.
  - generally by vapor diffusion only
- So you must keep it dry from all four sides
  - or come up with an approach that promotes inward drying better than outward wetting.

CONTROL LAYERS – PERFECT SLAB

- Dry and Warm Slab w/ RRNC
  - 4” of ¾” and up aggregate; no fines
  - 1 to 3” of extruded polystyrene
  - Poly vapor retarder (optional)
  - 4” high quality slab; all joints and edges sealed
  - Sealed sump basket
  - 3 or 4” passive vent from below slab to the roof
    - with electrical box nearby in attic for fan activation

CONTROL LAYERS – FOUNDATION

- Dry and Warm Foundation
  - Cast-in-place (or CMU or wood) foundation
    - capillary break between footing and wall
  - Quality exterior waterproofing
  - Exterior drain tile protected by rock & fabric
  - R-15 exterior insulation
    - extruded polystyrene or semi-rigid fiberglass
  - Good vertical drainage
    - with 6” impermeable cap

FOUNDATION SLAB & WALL SOLUTION

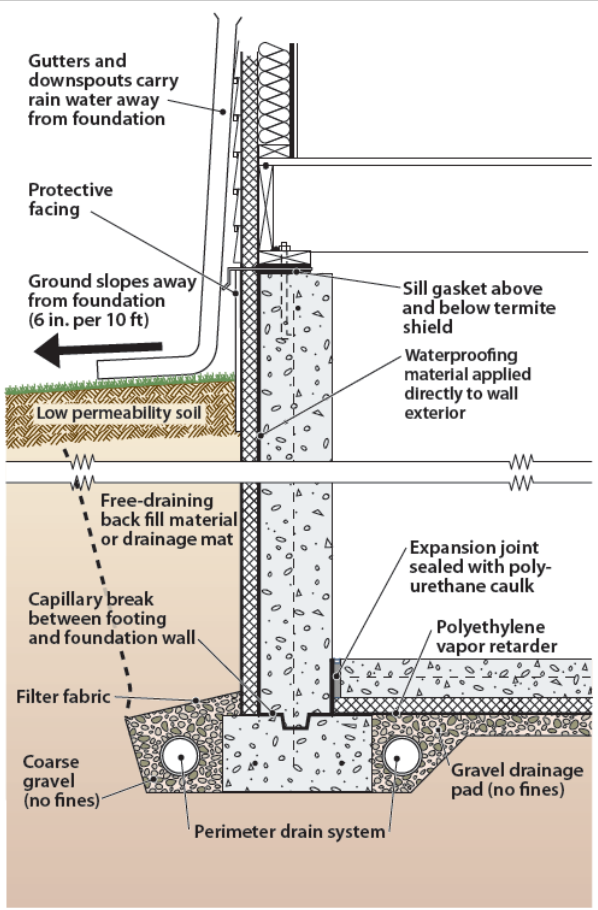


Figure 2-3: Components of Basement Drainage and Waterproofing System

Source: Oak Ridge National Laboratory

CONTROL LAYERS – ENHANCED ROOF

- Traditional Vented Attic
  - Ceiling drywall direct to trusses (no poly)
  - One pass closed-cell spray foam
    - sealed to the top plate, heel sheathing, and chutes
    - approximately 2” (R-12)
  - Blown-in insulation (R-40 to 50)
    - fiberglass @ 16” to 18”
    - cellulose @ 12” to 15”

CONTROL LAYERS – HYBRID ROOF

- For Sloped Roof or Conditioned Attic
  - Interior batt (R-21) between rafters or top chords
  - Structural sheathing
  - Peel and stick membrane
  - Exterior foam (R-30 - usually XPS or polyiso)
  - Flat 2x4 furring strips fastened through to frame
    - provides vent space w/ continuous soffit & ridge vents
  - OSB roof deck
  - Building paper and shingles

CONTROL LAYERS – FENESTRATION

- Windows Designed for Integration
  - Always use the highest quality, low U-value, warm-edge window you can afford that comes with …
    - a custom fit sill pan,
    - head flashing with end dams, and
    - flanges that are air/water tight with tabs to integrate with flashing and air/water control layer

CONTROL LAYERS – DUCTWORK

- What if the ductwork breaks through the air control and vapor control layer?
  - The duct must be absolutely air and vapor tight with proper insulation and impermeable covering.
  - Or you must reconfigure the control layers so the air and vapor control layers are outside of the ductwork and inside the dewpoint(s).

TIME FOR A QUICK PAUSE

- Questions
- Thoughts
- Reflections
- Discussion

3. WALL CASE STUDIES

- Desired Outcomes
  - comfortable
  - efficient
  - durable
  - healthy
  - resilient

- Desired Characteristics
  - accessible
  - easy to execute
  - cost effective
  - easy to maintain/repair
  - robust

=> Important Note: These are just three examples built upon the perfect wall and control layer methodology!

WALL A: EXTENDED PLATE WALL (EPW)

- EPW was developed by Home Innovation Research Labs
  - Driven by demand for improved energy efficiency
    - stricter code requirements
    - increasing consumer expectations
  - Lack of market penetration for “high-R” walls
    - low market adoption for exterior continuous insulation
    - cost, complexity, and lack of industry-wide training
  - Need for a durable and robust high-performance wall that is flexible for both site-built and panelization

EXTENDED PLATE WALL: SOLUTION

Interior View

Exterior View

High-R wall with rigid foam insulation interior to the wood structural sheathing

EPW: KEY CHARACTERISTICS

- The bottom and top plates are one dimension larger than the studs.
- There is a layer of 2” rigid insulation in the space between the stud framing and OSB sheathing.
- Double rim board (beam) functions as a header, and can be inset 1” to provide space for a continuous insulation thermal break.

EPW: CONTROL LAYERS

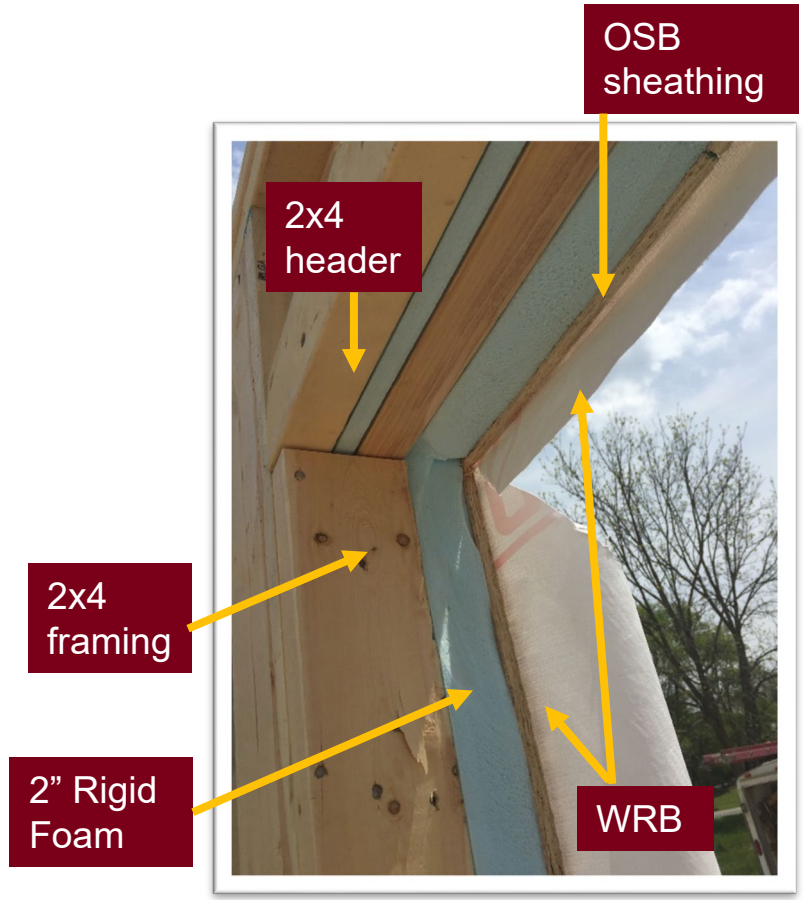
- Water Control Layer
  - WRB, shingle-applied, fastened to OSB sheathing or
  - Treated OSB sheathing (liquid-applied or taped seams)
- Air Control Layer
  - Sealed rigid foam or
  - WRB or taped sheathing
- Thermal Control Layers
  - Continuous rigid foam insulation
  - Cavity-fill insulation

EPW: CONTROL LAYERS

- Vapor Control Strategies
  - Sealed rigid foam provides a distinct, centrally-located vapor control plane with effective drying to the direction from which the source moisture originated.
  - Interior vapor retarder recommended in very cold climates and buildings with high indoor humidity
    - preferably a kraft-facer or “smart” vapor retarder.

EPW: ADVANTAGES

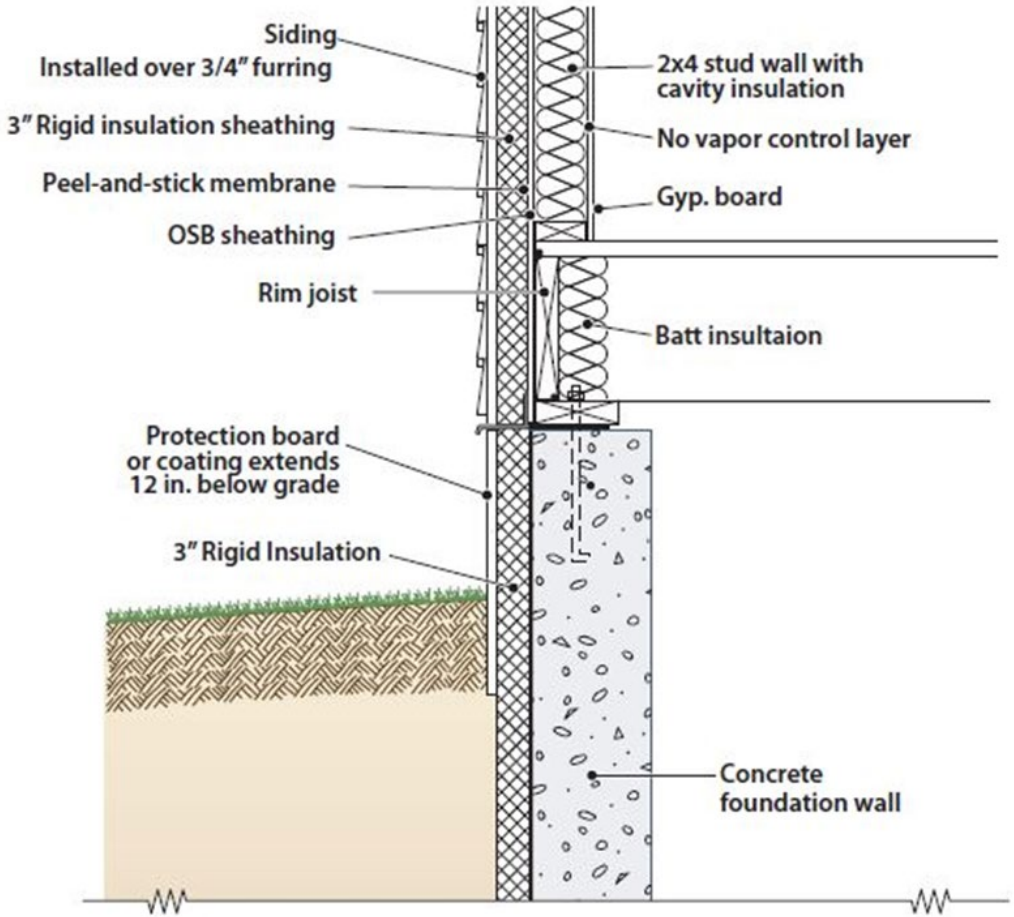
- Uses standard framing and air sealing techniques
  - standard nails in a common fastening schedule (3-1/2” @ 3” edge / 6” field)
- Exterior OSB allows conventional methods for
  - drainage plane treatment
  - window installation
  - cladding attachment

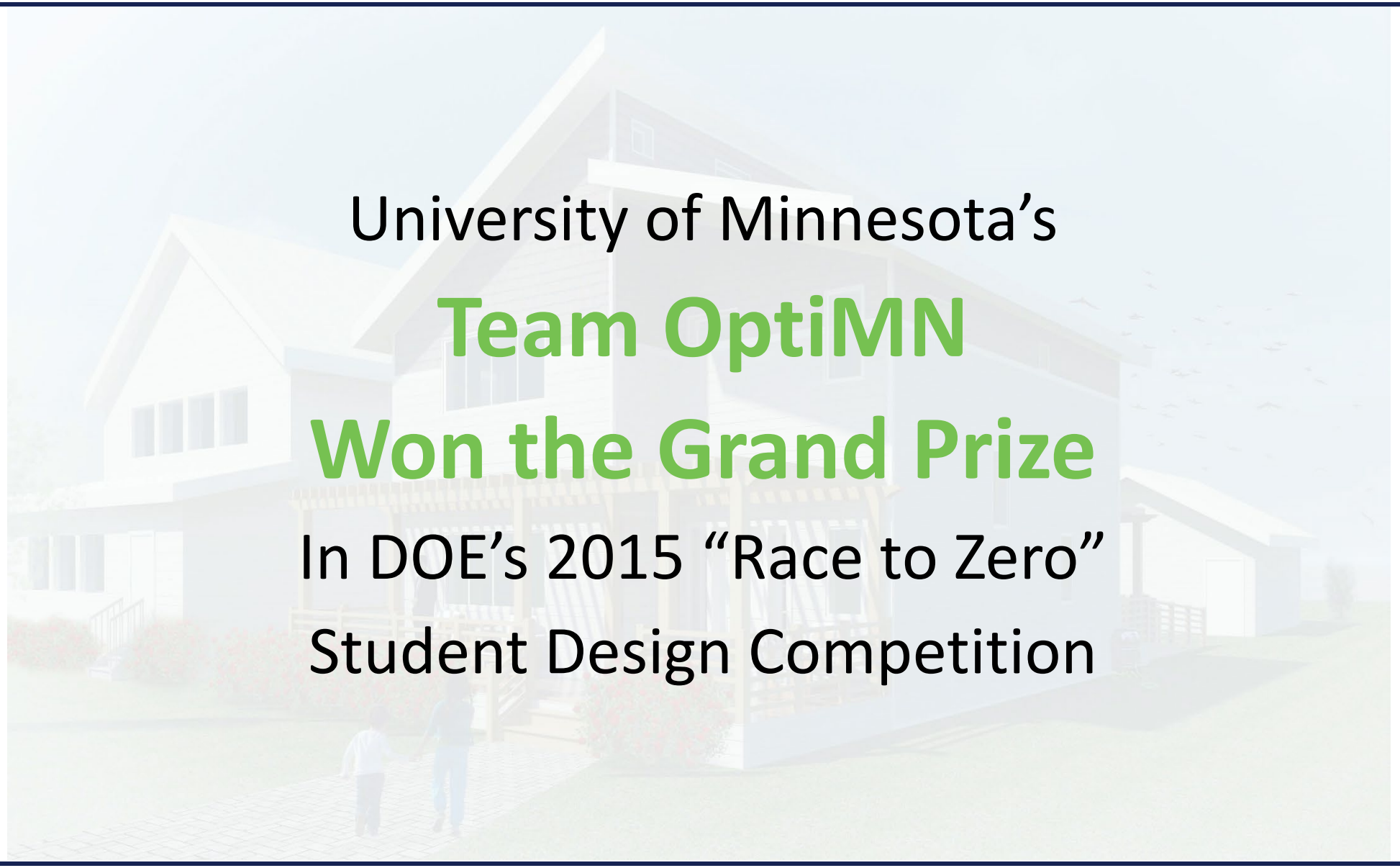


EPW: SUMMARY

- Suitable for use in all climate zones
- Flexible configurations to provide above-code performance
- 95% of the wall area is free of thermal bridging
- Can be panelized for packaged delivery to the site
- Estimated cost is less than comparable code wall with continuous exterior insulation

WALL B: OPTI-MN (HYBRID) WALL





University of Minnesota's

Team OptiMN

Won the Grand Prize

In DOE's 2015 "Race to Zero"

Student Design Competition

INTRODUCING | The Impact Home

PERFORMANCE GOALS | Site in DOE Climate Zone 6

Durable & Long-Lasting

ZERO ENERGY READY HOME
U.S. DEPARTMENT OF ENERGY

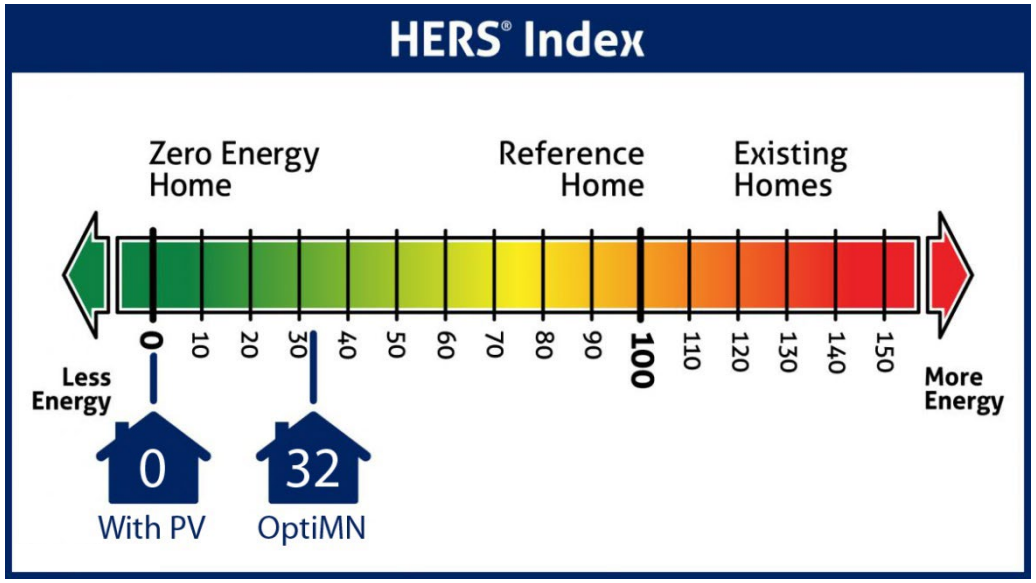
Fortified Home

FORTIFIED HOME

Indoor Air Quality

EPA Indoor airPLUS

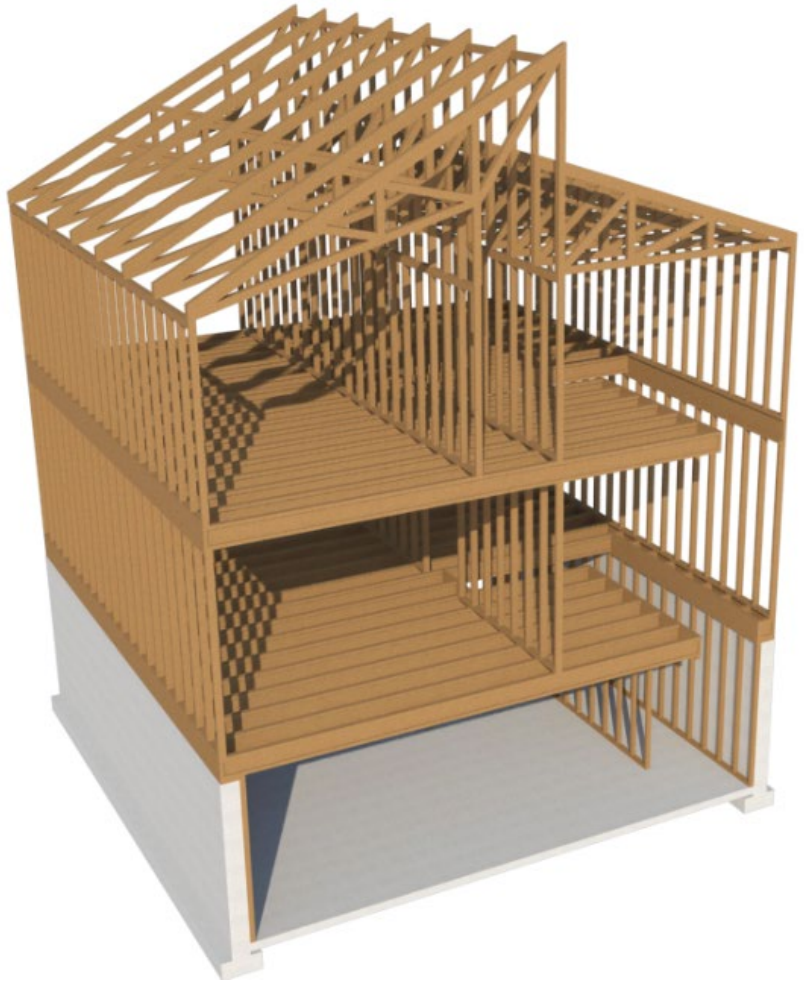
Energy Efficient | Zero Energy Ready

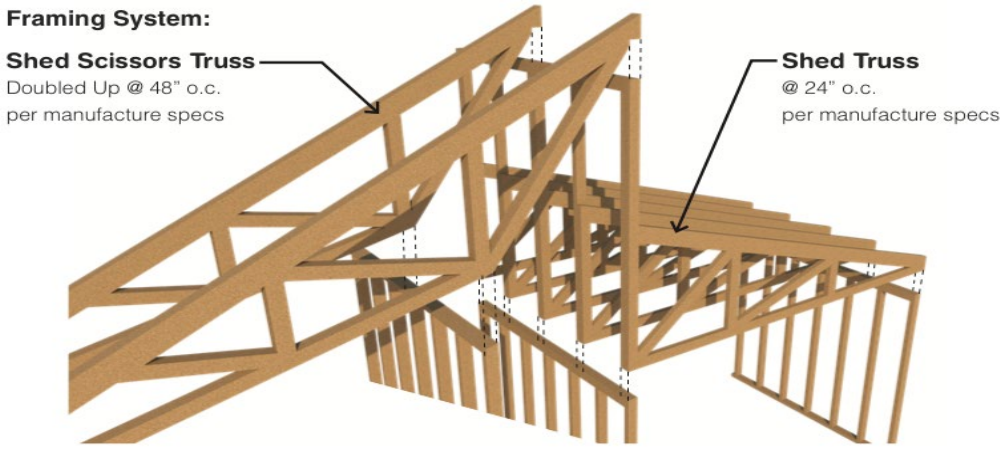


Water Stewardship

WaterSense
Meets EPA Criteria

CONSTRUCTABILITY





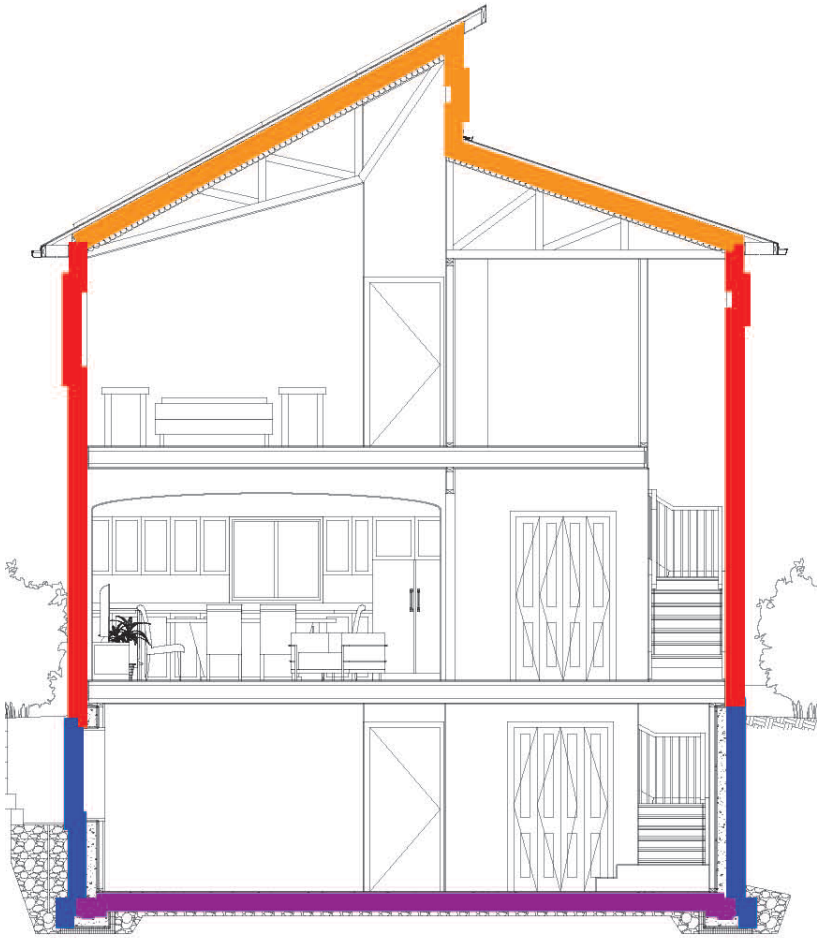
Approachable and Appropriate Construction Materials and Methods

- Simplified design and shape
- Based on traditional construction materials and techniques

ENCLOSURE DESIGN | 4 Control Layers

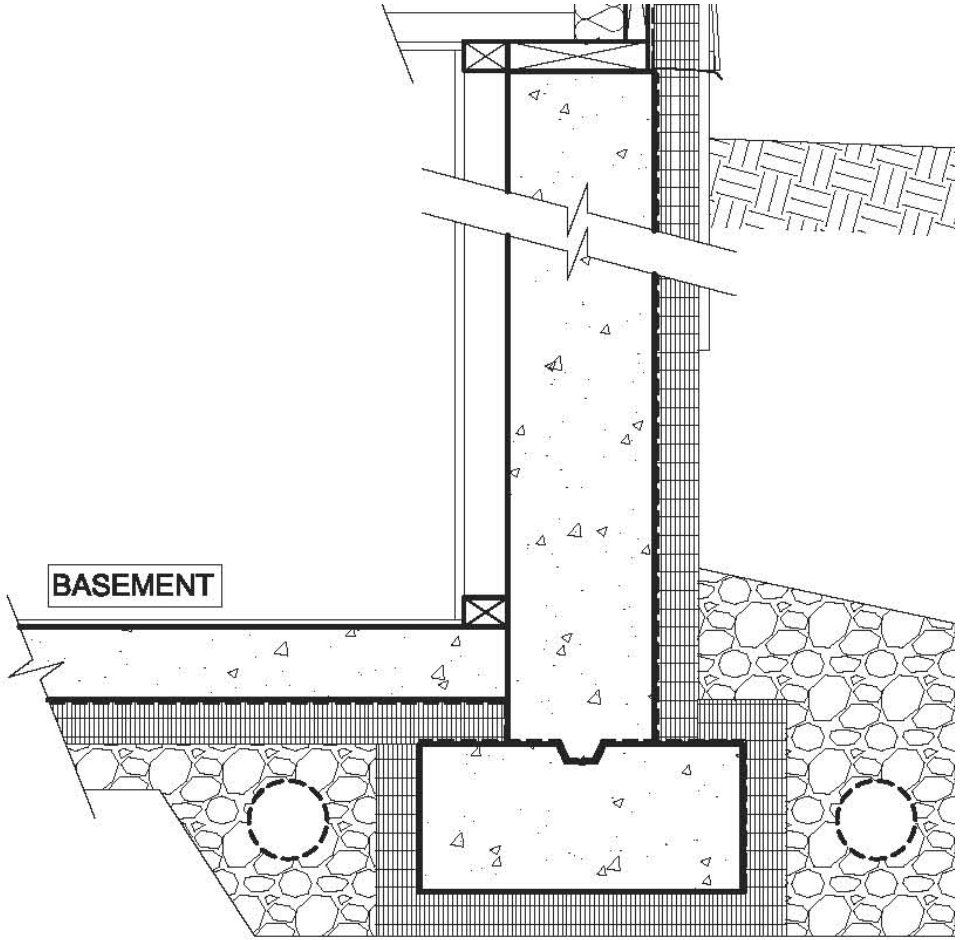
- **Thermal** insulation to retard heat flow
- **Water** control membrane to prevent wetting of moisture sensitive materials
- **Air** barrier to stop unwanted heat and moisture flow
- **Vapor** retarder strategy to slow wetting, yet allow drying

  - **Orange**: W.R. Grace Perm-a-Barrier
  - **Red**: Huber ZIP sheathing system
  - **Blue**: Foundation waterproofing
  - **Purple**: Cross-laminated polyethylene membrane



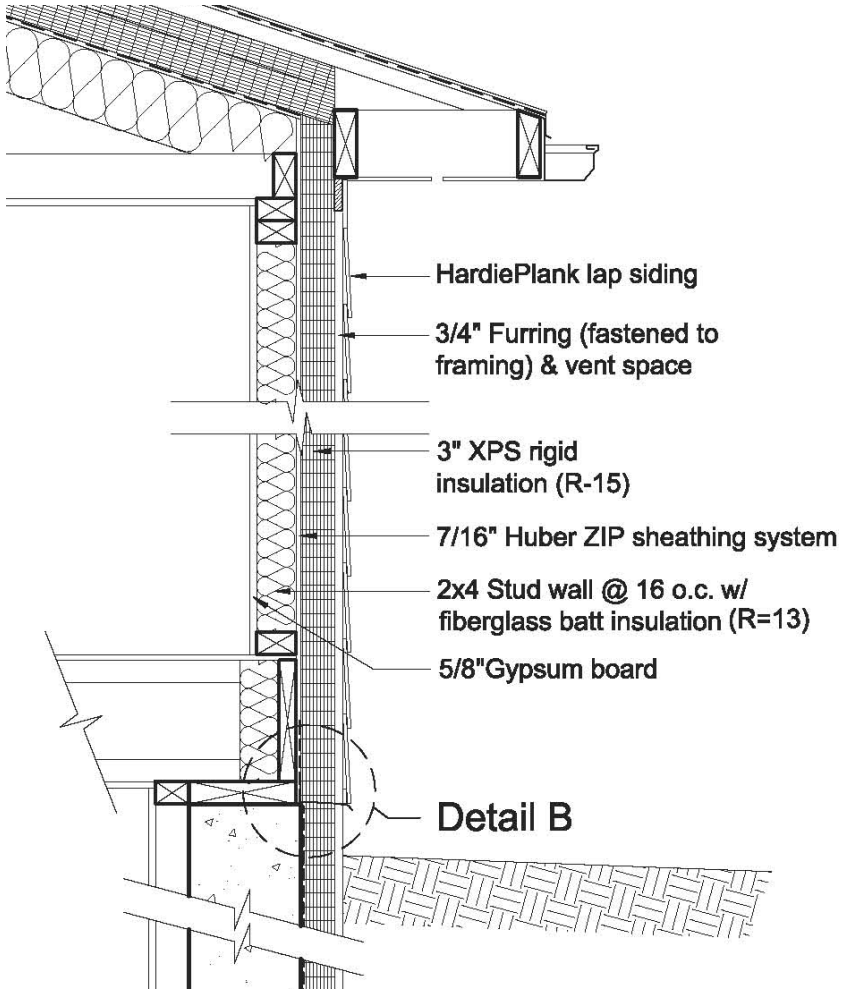
FOUNDATION STRATEGY | Airtight, Dry, & Warm

- Exterior waterproofing and insulation
  - Slab is R-10
  - Footing is R-10
  - Foundation wall is R-15
- Good drainage
- Capillary breaks



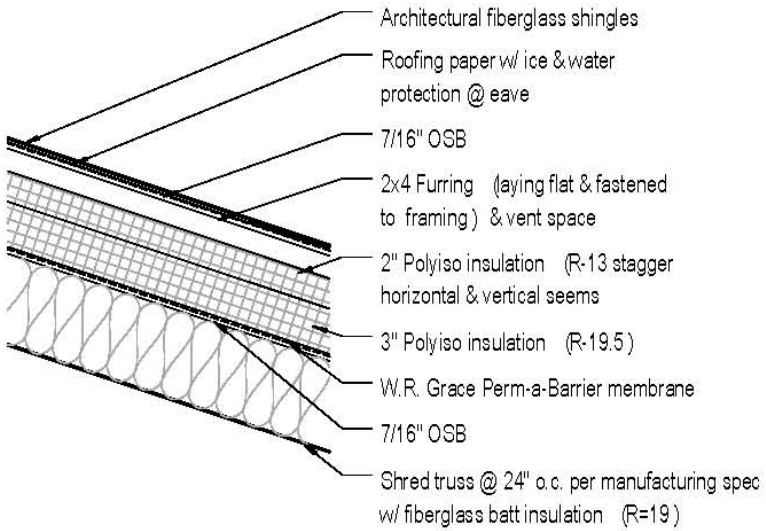
HYBRID WALL STRATEGY | Robust & Easy to Construct

- The **air, water, and vapor control layer** is over a traditional wood-frame wall
- Then **rigid insulation, vented rainscreen, and siding** is added to the exterior
- This approach limits moisture movement, yet facilitates **bi-directional drying**



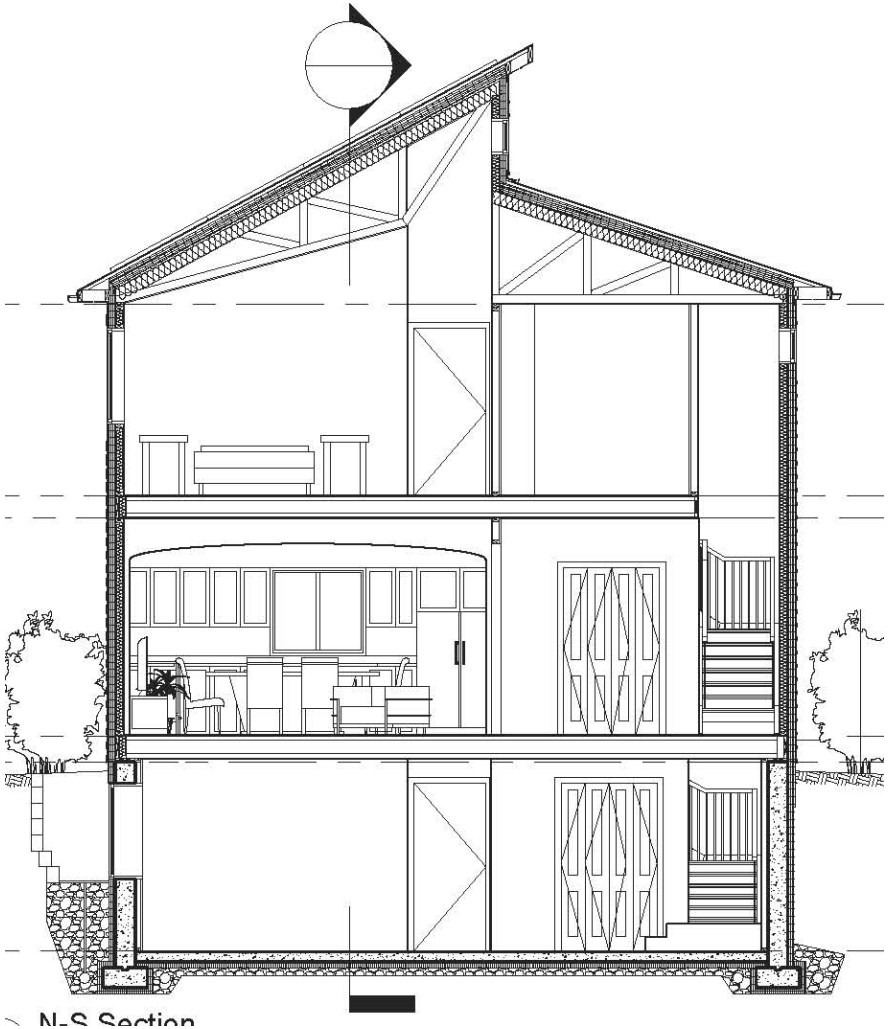
HYBRID ROOF STRATEGY | Adds Flexible Space & Robust

- Provides additional space for **design, living, storage, and mechanicals**
- Manages **moisture and mitigates ice dams** much better than traditional sloped ceilings



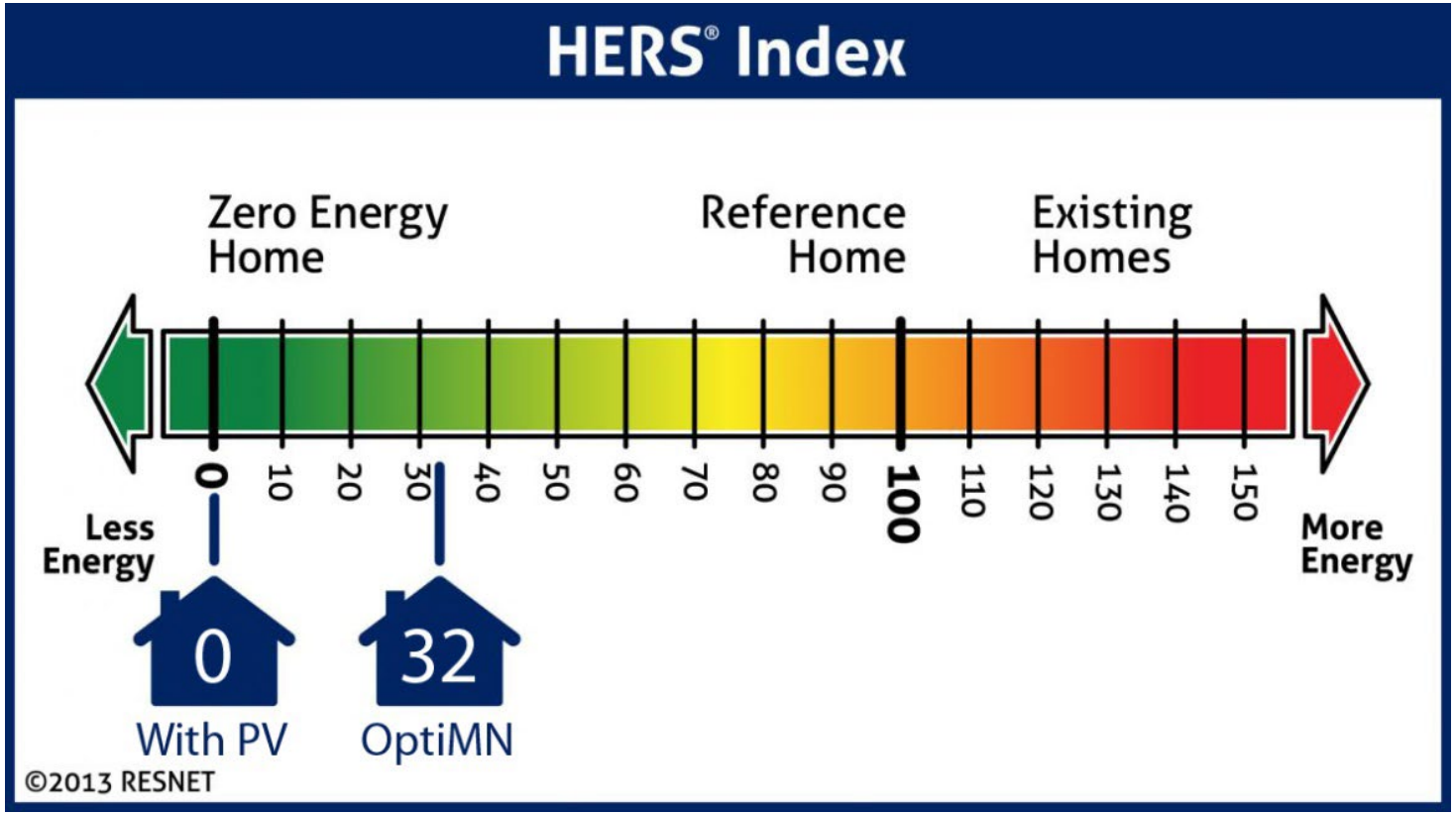
NORTH ROOF DETAIL

Total R-value = 53
Insulation 60/40 Ratio



N-S Section

PERFORMANCE



Heating, cooling, and water heating costs is approximately **$420 / year**

OPTI-MN (HYBRID): CONTROL LAYERS

- Water Control
  - Drainage behind cladding
  - “Peel & stick” membrane on sheathing
- Air Control
  - “Peel & stick” membrane on sheathing
- Vapor Control
  - “Peel & stick” membrane on sheathing
- Thermal Control
  - R-15 fiberglass in cavity
  - R-15 extruded polystyrene on exterior

OPTI-MN (HYBRID): SUMMARY

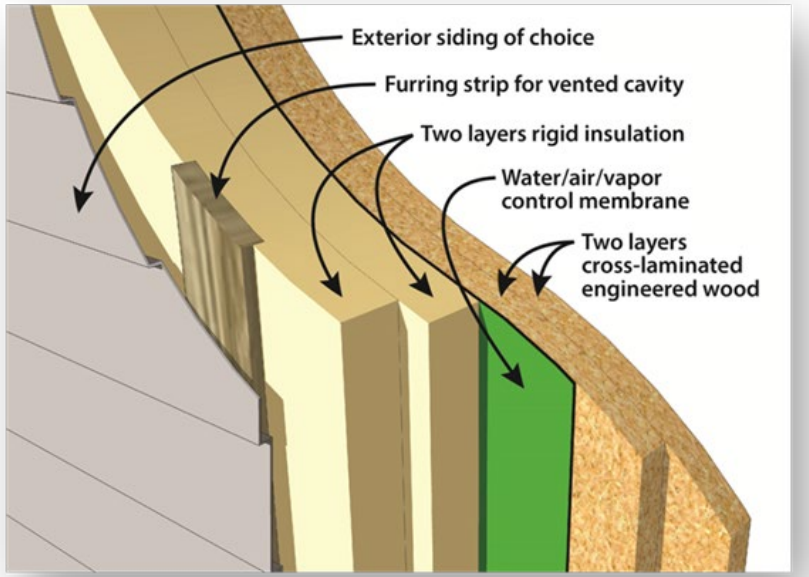
- Pros
  - Simple and familiar framing
  - No interior air sealing required; can glue drywall
  - High R-value; superior airtightness
  - Strong drying potential both inside & out
- Cons
  - Cost of exterior control layers
  - Exterior furring strips must hit the framing
  - Window trim???

WALL C: SOLID PANEL STRUCUTRAL SYSTEM

- 2016 DOE Building America funded project to validate:
  - a new enclosure technology
  - delivered by a single enclosure contractor
- Demonstrate market acceptance with focus on affordable housing

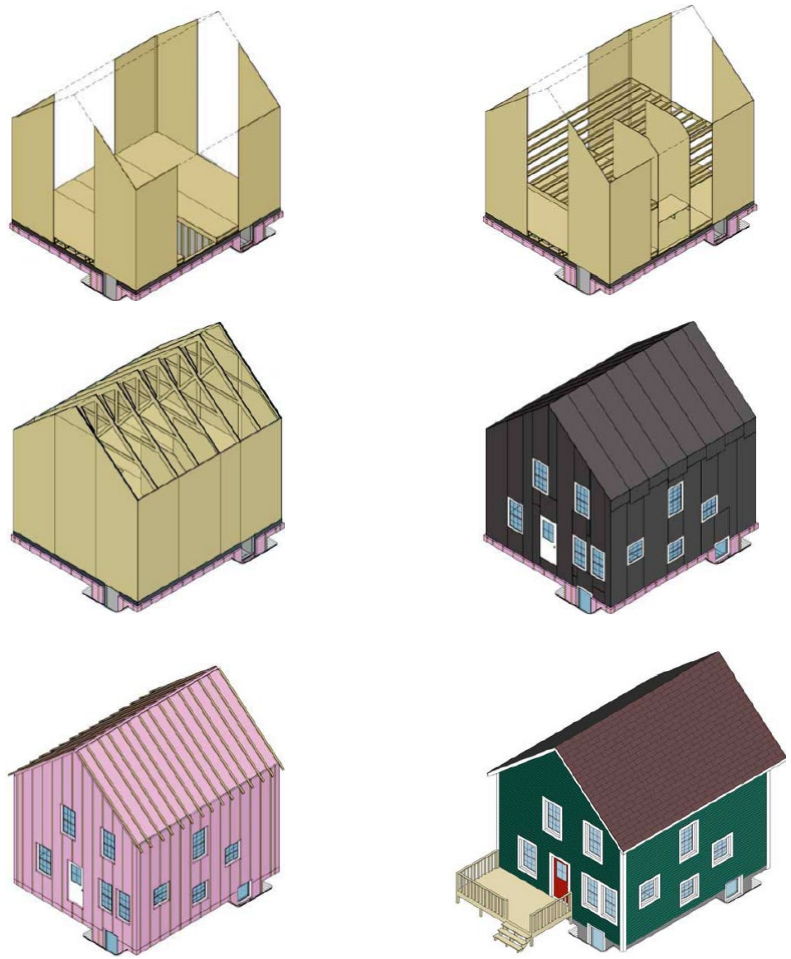
SPS SYSTEM: MARKET DRIVERS

- Reduce the cost of the “Perfect Wall”
- Drive down the cost of the structure
  - Requiring less labor and skill
- Simplify the application of the exterior control layers
- Protect critical control layers
- Speed enclosure time (esp. dry-in)
- Stronger with enhanced resilience



SPS: BENEFIT OF SINGLE ENCLOSURE CONTRACTOR

- Building process developed by MonoPath
  - reduces installation errors
  - speeds overall construction time
  - reduces overall construction cost
- More consistent performance outcomes
  - reliable insulation quality and performance
  - improved moisture management
  - remarkable and repeatable airtightness




662
Researching New Construction Technology
Project 20-30
A Joint Research Project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GRACE
Bituthene
GRACE
Perm-A-Barrier
GRACE VYCOR PLUS
GRACE VYCOR


GRACE
Bituthene
Perm-A-Barrier


METROPOLITAN

SPS SYSTEM: CONTROL LAYERS

- Water Control
  - Drainage behind cladding
  - “Peel & stick” membrane on wall panel
- Air Control
  - “Peel & stick” membrane on wall panel
- Vapor Control
  - “Peel & stick” membrane on wall panel
- Thermal Control
  - R-20 extruded polystyrene on exterior

SPS SYSTEM: SUMMARY

- Pros
  - Quick erection to dried-in & secured
  - Can reduce labor time and skill
  - Extremely robust performance
  - Potential strength advantages???
- Cons
  - Some design limitations until system is validated
  - Upfront engineering costs
    - DOE BA has funded a current project to address this issue!

FINAL NOTES & THOUGHTS

- High-performance houses will require new enclosure strategies and systems
  - Achieve higher insulation levels
  - Improve water, air, and vapor control layers
  - Employ better drying strategies
  - Embrace more robust delivery systems
  - Provide enhanced resilience

FINAL NOTES & THOUGHTS

- High-performance enclosures will demand:
  - Integrated systems approach to low-load HVAC+DHW
  - Increased attention to indoor air quality
    - source control
    - ventilation
    - distribution
  - Improved make-up air solutions for
    - range hood
    - clothes dryer

RESOURCES FOR H-P WALLS

- DOE Building America Resources
  - General Energy Information (EERE)
  - DOE Zero Energy Ready Home (ZERH)
    - Tour of Zero
  - Top Innovations “Hall of Fame”
  - Building America Solution Center
  - Building Science Advisor

World-Class Research…

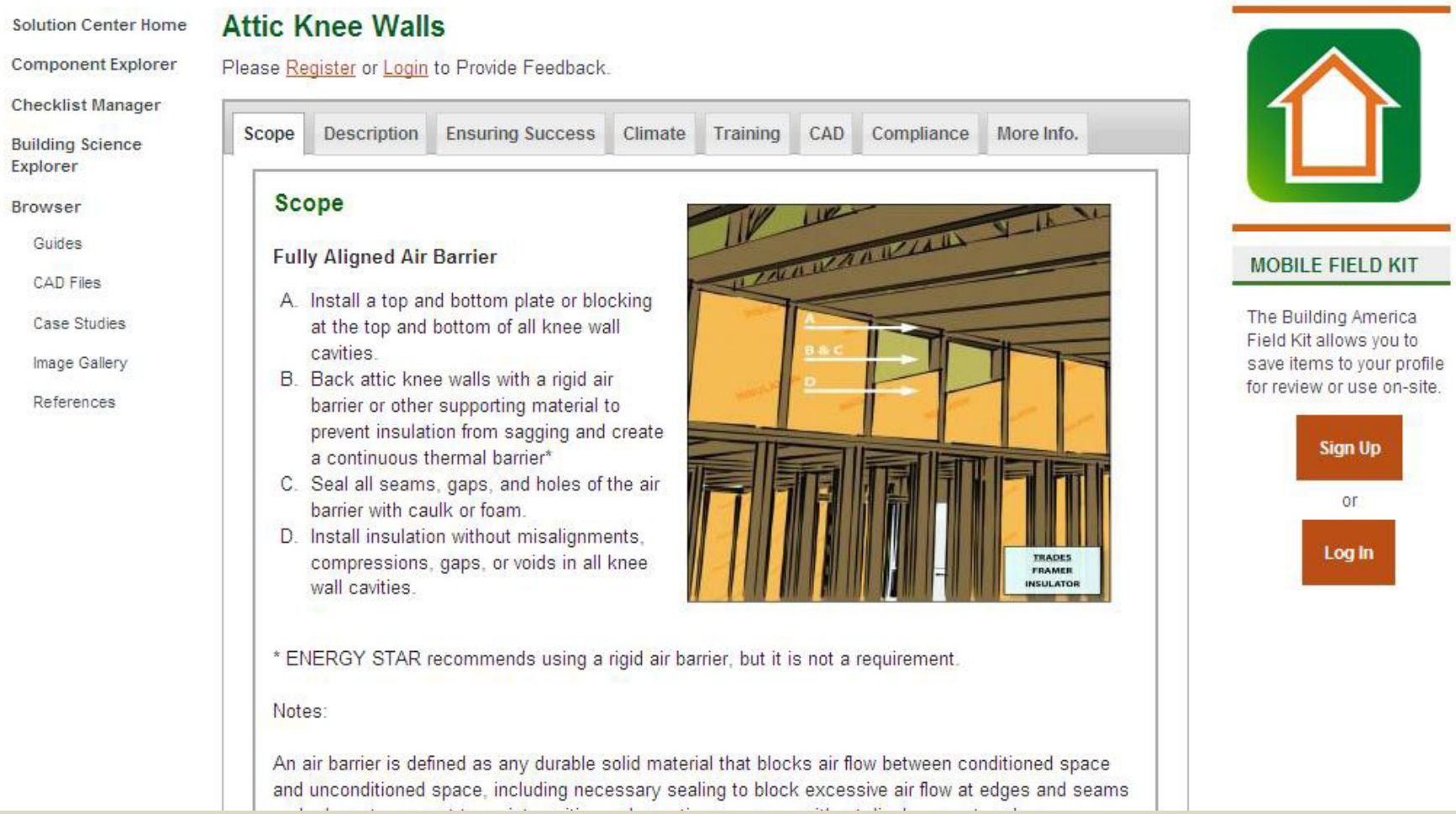
Building America Solution Center

BASC.energy.gov

…At Your Fingertips

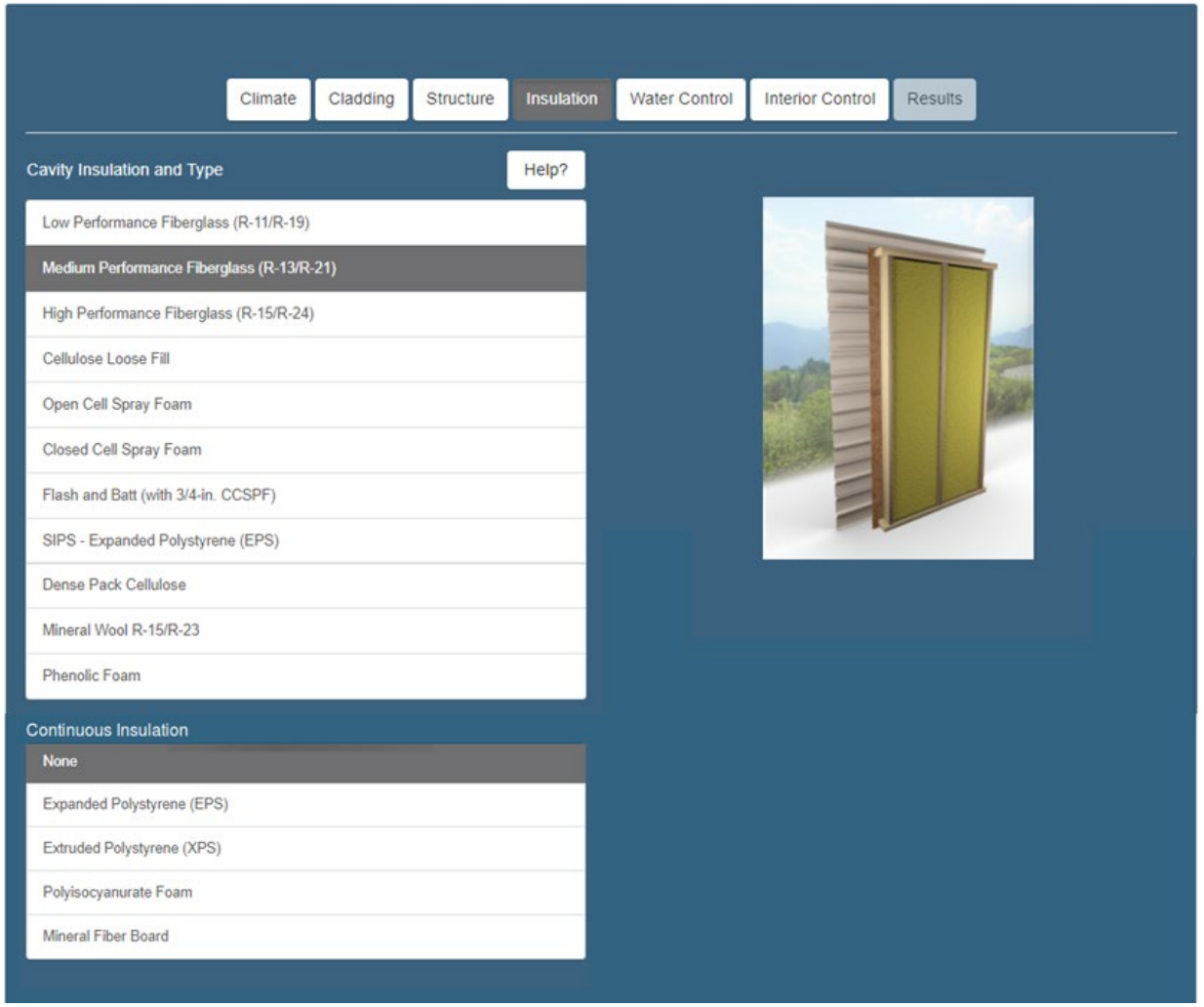
Quick Tour: Guides

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy



Scope: Clearly defines and bounds the topic in a way builders and remodelers can contractually obligate their subcontractors.

ORNL Building Science Advisor: Input Screen



Improvements:

- Number of input screens reduced;
- More obvious “Help” menu;
- More “drop down” menu selections;
- “Results” button requires complete input selection;
- More thickness variations in the continuous insulation menu; and
- Better image graphics.

ORNL Building Science Advisor: Results Screen

- Durability indicator/dial
- R-value comparison with Code
- “Drop down” menu capability

BACKGROUND ARTICLES FOR H-P WALLS

- BSI-028: Energy Flow Across the Enclosure
  - Joseph Lstiburek, 2009
- BSI-039: The Five Things
  - Joseph Lstiburek, 2010
- BSI-001: The Perfect Wall
  - Joe Lstiburek, 2010 (revised)
- BSI-090: Joseph Haydn Does the Perfect Wall
  - Joe Lstiburek, 2015

Available at buildingscience.com

REFERENCE MATERIALS FOR H-P WALLS

- Building Science for Building Enclosures
  - John Straube & Eric Burnett (2005)
- High-Performance Enclosures
  - John Straube (2012)
- Builder's Guide to Continuous Insulation
  - Peter Baker & Joseph Lstiburek (2014)
- Moisture Control Guidance for Buildings
  - U.S. EPA (2013)
  - epa.gov/sites/default/files/2014-08/documents/moisture-control.pdf

BUILDING AMERICA RESOURCES FOR H-P WALLS

- Getting Enclosures Right in ZERH
  - https://www.energy.gov/eere/buildings/downloads/zerh-webinar-getting-enclosures-right-zero-energy-ready-homes
- Building America Measure Guideline
  - https://www1.eere.energy.gov/buildings/publications/pdfs/building_america/incorporating-thick-layers-exterior-insulation.pdf
- Building America Solution Center
  - https://basc.pnnl.gov/resource-guides/continuous-rigid-insulation-sheathingsiding
  - https://basc.pnnl.gov/code-compliance/continuous-insulation-claddingfurring-attachment-code-compliance-brief

TIME FOR A QUICK PAUSE

- Questions
- Thoughts
- Reflections
- Discussion

Contact Information

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