From Control Layers to High-Performance Enclosures

Session for: Energy Design Conference

Presented by: Patrick Huelman
University of Minnesota
Cold Climate Housing Program

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FROM CONTROL LAYERS TO HIGH-PERFORMANCE ENCLOSURES

- Part 1: Making a Case for Robust H-P Homes
- Part 2: It's All About the Control Layers
- Part 3: Defining the "Perfect Wall"
- Part 4: Wall Case Studies for H-P Homes

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

OVERARCHING THEMES

- We can and must do better!
  - Challenge ourselves towards better performance
- Existing technology can get us there, but …
  - We need to reduce the focus on products.
  - We must embrace more robust systems.
  - We need improvement in design & execution.
- For major advances in performance, we will need more robust designs, technologies, and processes.

KEEPING OUR EYE ON THE BALL

- Is it possible that we are putting our “eggs into a pretty fragile basket”?
  - Is it possible that the “basket” is getting increasingly fragile due to the nature of the industry, codes, materials, buyers, etc.?

»

- Are we using designs, systems, materials, and operations that are falling short of our performance expectations.

KEEPING OUR EYE ON THE BALL

- Is it possible that we have over-invested in products and under-invested in good design and proper execution?
- Are we not being realistic about the process?
  - Are we investing in risky designs, systems, and materials and hoping for perfect execution?
  - Are we counting on perfect homeowner operation and maintenance?

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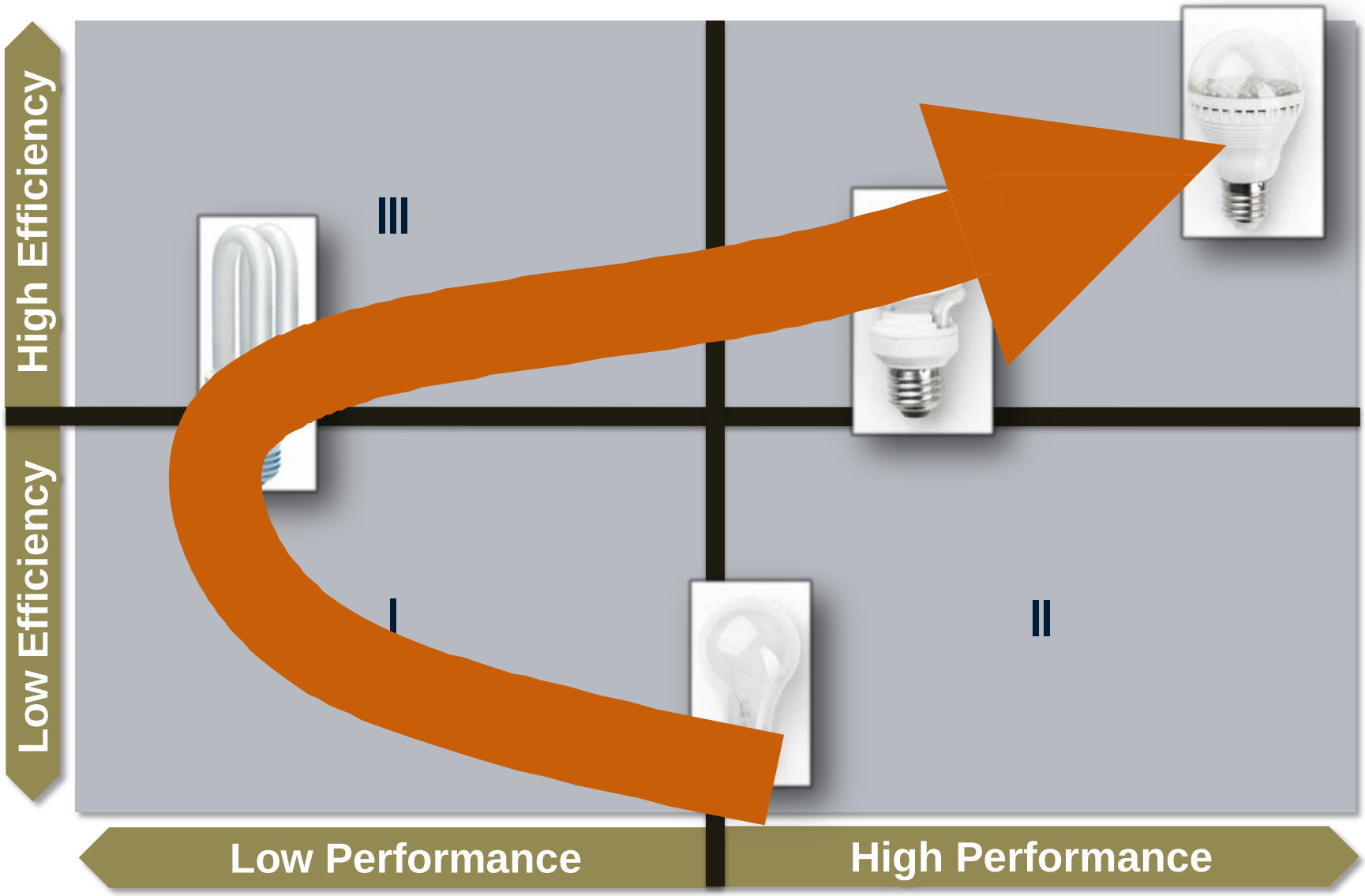

DOE Zero Energy Ready Home Program

ZERO
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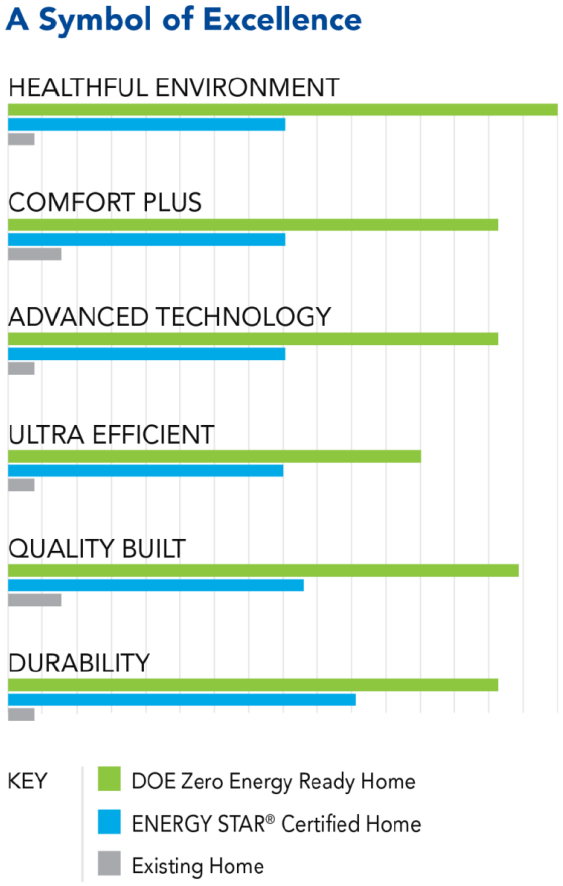


1. MAKING THE CASE FOR ROBUST

- What must we do to move away from the fragile edge and move towards more robust
  - Designs,
  - Systems,
  - Materials,
  - Methods, and
  - Operation?

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, nature, or client throw at them!

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 fickle” to handle the real life situations they encounter.

MAKING THE CASE FOR ROBUST

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

MAKING THE CASE FOR ROBUST

- Robust: Don't think of it as a thing, but more of a conceptual way of evaluating new designs, systems, materials, execution, and operation.

- There are a number of ways to think of robust.
  - It is idiot proof, bullet proof, and unlikely to fail.
  - If it fails, it won't hurt anything else.
  - If it fails, it will be easy to repair or replace.
  - If it fails, there is a planned back-up or redundancy.

MAKING THE CASE FOR ROBUST

- A Call for High-Performance Houses
  - That meet our expectations today and in the future!

- But 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 materials.
    - or make it easy to repair and/or replace key components
  - develop a more predictable delivery system.
  - provide continuous feedback to the occupant.

BUILDING SCIENCE REVIEW

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

BUILDING SCIENCE REVIEW

- **Heat Flows**
  - Transmission losses/gains
  - Air exchange losses/gains
  - Solar gains
  - Internal gains
- **Air Flows**
  - Paths
  - Pressures
- **Moisture Flows**
  - Liquid
    - gravity
    - capillarity
  - Vapor
    - diffusion
    - air transport

2. THE 4 CONTROL LAYERS

- Every enclosure element must have four control layers!

- In rank order, they are:
  - Thermal control (???)
  - Water control
  - Air control
  - Vapor control

THERMAL CONTROL LAYER(S)

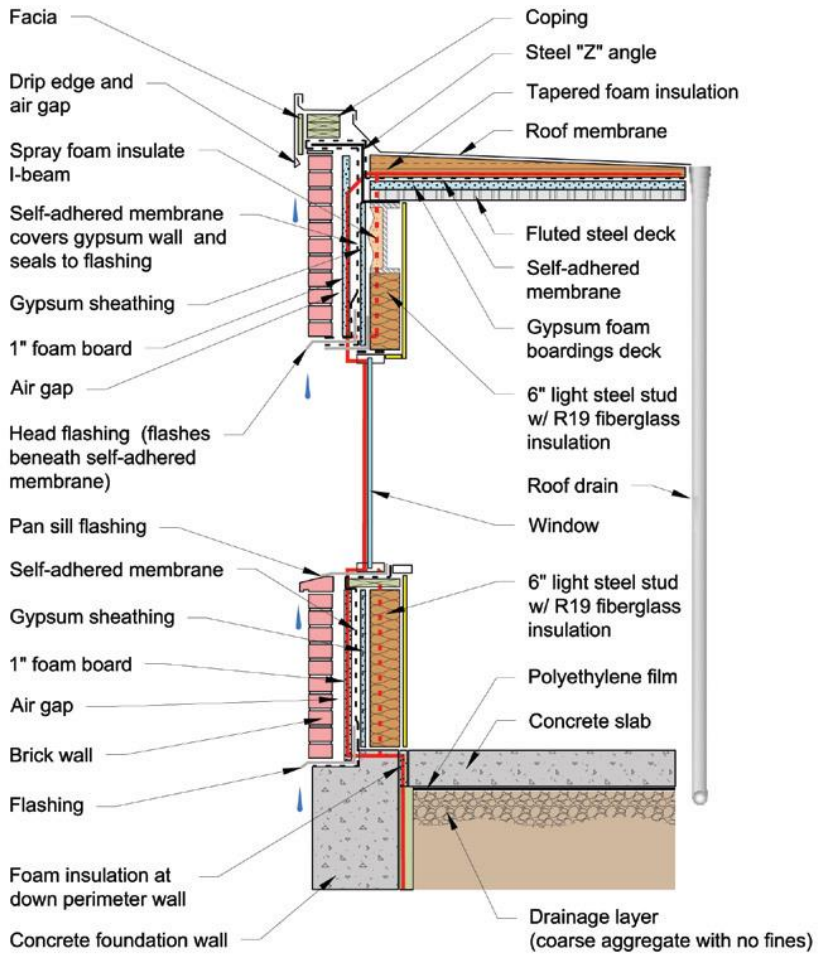
- General Overview
  - The intent is to slow the transmission of heat energy going from warm to cold.
    - Driver is the temperature difference
    - Primarily set by indoor and outdoor conditions
- This is the easy one!
    - How much?
    - Where?
    - What type?

THERMAL CONTROL LAYER(S)

Insulation	MN Code	ZERH	NZE*
– Ceiling (flat)	50	50	60
– Walls	20	25	40
– Fenestration	3	4	5
– Floor (frame)	30	40	50
– Foundation	15(10+)	15	20
– Slab	0	0	10

* 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
    - You can (should) take steps to reduce the drivers
- This is absolutely critical,
  - especially as we remove drying potential with increased insulation, reduced air flow, and multiple vapor retarders!

KEYS TO WATER MANAGEMENT

- Sources of Bulk (Free) Water
  - Precipitation
  - Groundwater
  - Melting ice & snow
  - Condensation
  - Plumbing leak
  - Spills & overflows

KEYS TO WATER MANAGEMENT

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

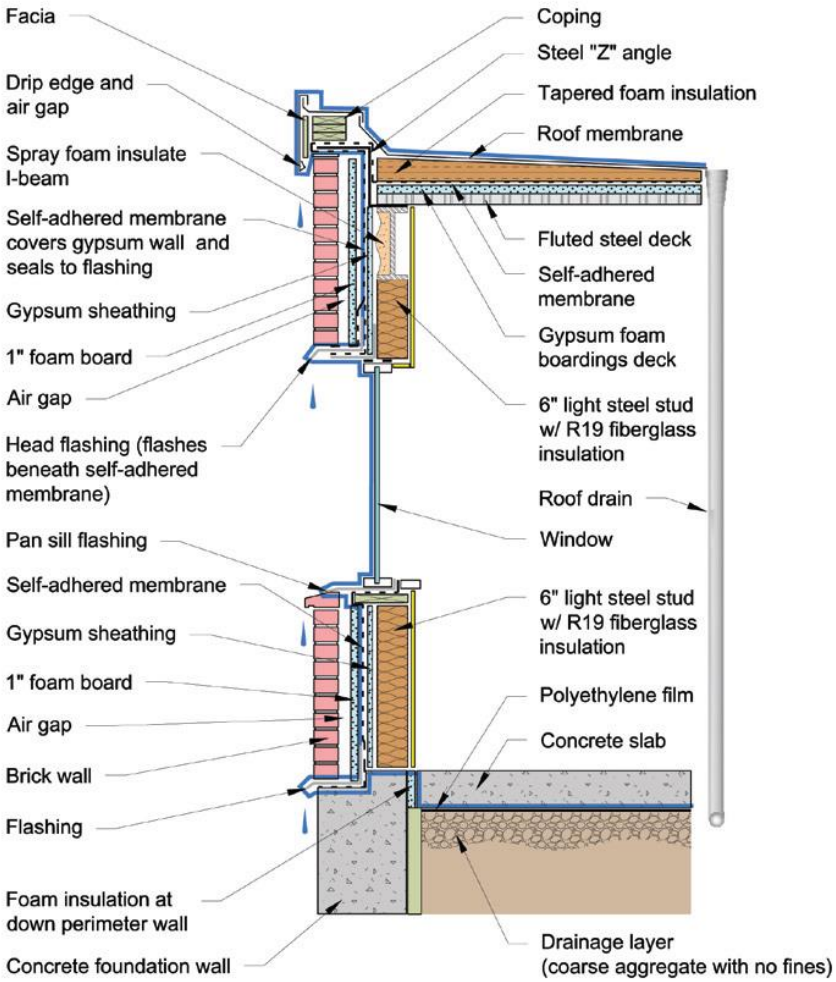
- Highest Level Principle
  - Use gravity to shed water down and out
  - To manage rain, surface, and ground water

- Drain everything!!!

KEYS TO WATER MANAGEMENT

- What can't be drained must have a robust back-up.
  - A leak is not a leak, if leaks outside, it doesn't affect any moisture susceptible materials, or grows mold within the indoor environment!
- The back-up can be …
  - Another water management layer,
  - A secondary system for water removal, or
  - Storage with a solid drying strategy.

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 can create problems.
    - Primary driver is air pressures
    - You can (and must) manage the pressure difference
- This is absolutely essential in modern construction.

AIR CONTROL LAYER(S)

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

AIR CONTROL LAYER(S)

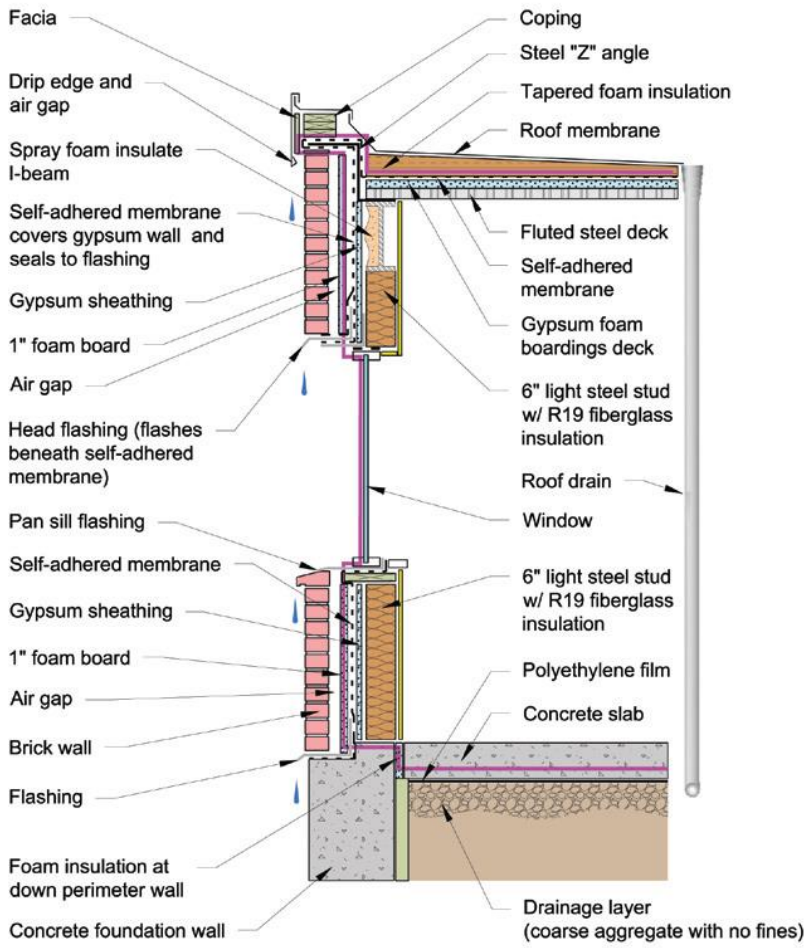
Airtightness	MN Code	ZERH	NZE
– ACH @ 50PA	3 ACH	2 ACH	1 ACH

AIR CONTROL LAYER(S)

- Where does it belong?
  - Inside
  - Outside
  - In between
  - Both

- 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 vapor pressure
    - That vapor pressure can (and should) be managed
- While it might not seem as critical as the other layers, it can't be ignored in …
    - Very cold climates
    - Hot humid climates
    - High humidity environments

VAPOR CONTROL LAYER(S)

- General Overview (continued)
  - As the thermal insulation increases the vapor permeance must decrease.
  - Today (due to air-conditioning) you must manage vapor from both directions.
  - And if anything gets wet, generally the only drying potential is by vapor diffusion so there must be a clear drying direction.

VAPOR CONTROL LAYER(S)

- Theoretical Framework
  - 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)

- Current building code (since 1991) requires a Class 1 or 2 vapor retarder
  - 1 perm or less on the warm side in winter.
- Code doesn't address exterior vapor retarders for summer conditions.
  - but inward vapor pressure is real depending on cladding choices
  - and best practice would suggest you must design for inward protection

VAPOR CONTROL LAYER(S)

- 1 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 can be a tricky number!
  - Generally lower than needed to prevent wetting.
  - However, it can be safe, if it is used in the proper location.
  - The material surface must be warm enough to prevent condensation.

VAPOR CONTROL LAYER(S)

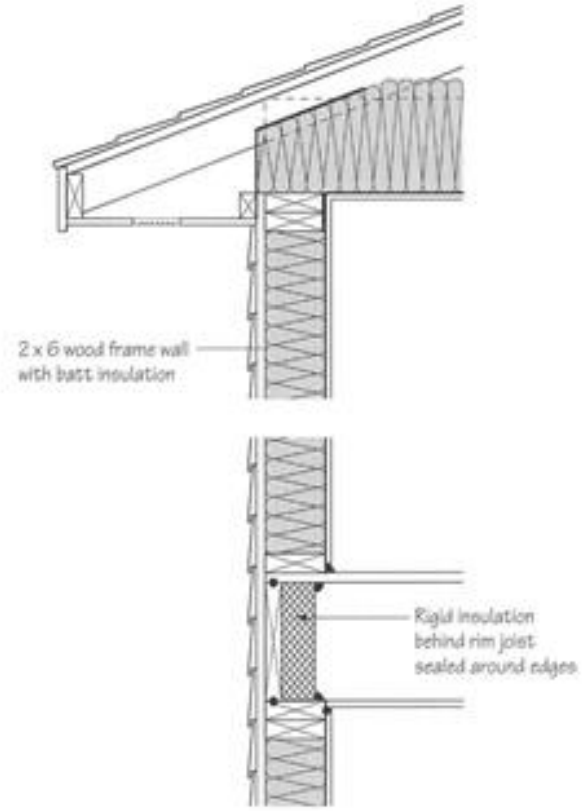
- So, this is more of a strategy rather than a specific layer.
  - Is there a proper vapor throttle to prevent vapor wetting of moisture susceptible materials from inside out and/or outside in?
  - Is there a clear drying direction along with sufficient energy for all moisture susceptible materials?

THE MODERN ENCLOSURE CONUNDRUM

- It gets wet from outside in and inside out!
  - In general, it will wet outward in winter and inward in summer.
- Things will get wet at some point due to imperfect design, execution, or operation.
- Therefore, all moisture susceptible materials must be able to dry out.
  - that can be outward in winter; inward in summer
  - except below grade, which can only dry inward.

THE MODERN ENCLOSURE CONUNDRUM

- Has the 2x6 cavity insulated wall hit the end of the road for climates that experience both heating and cooling?
  - Too little thermal control
  - Too risky / not robust
    - requires high-end execution
  - Too little drying potential



THE MODERN ENCLOSURE CONUNDRUM

- Risks Go Way Up With …
  - Poor bulk water control
  - Cladding that is not drained & vented
    - especially for reservoir claddings
  - Significant air-conditioning use
    - increased and longer operation
    - lower indoor temperature and RH

3. HIGH-PERFORMANCE ENCLOSURES

- The “Perfect” Approach
  - Walls
  - Roof
  - Slab
  - Foundation

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

PERFECT H-P ENCLOSURES

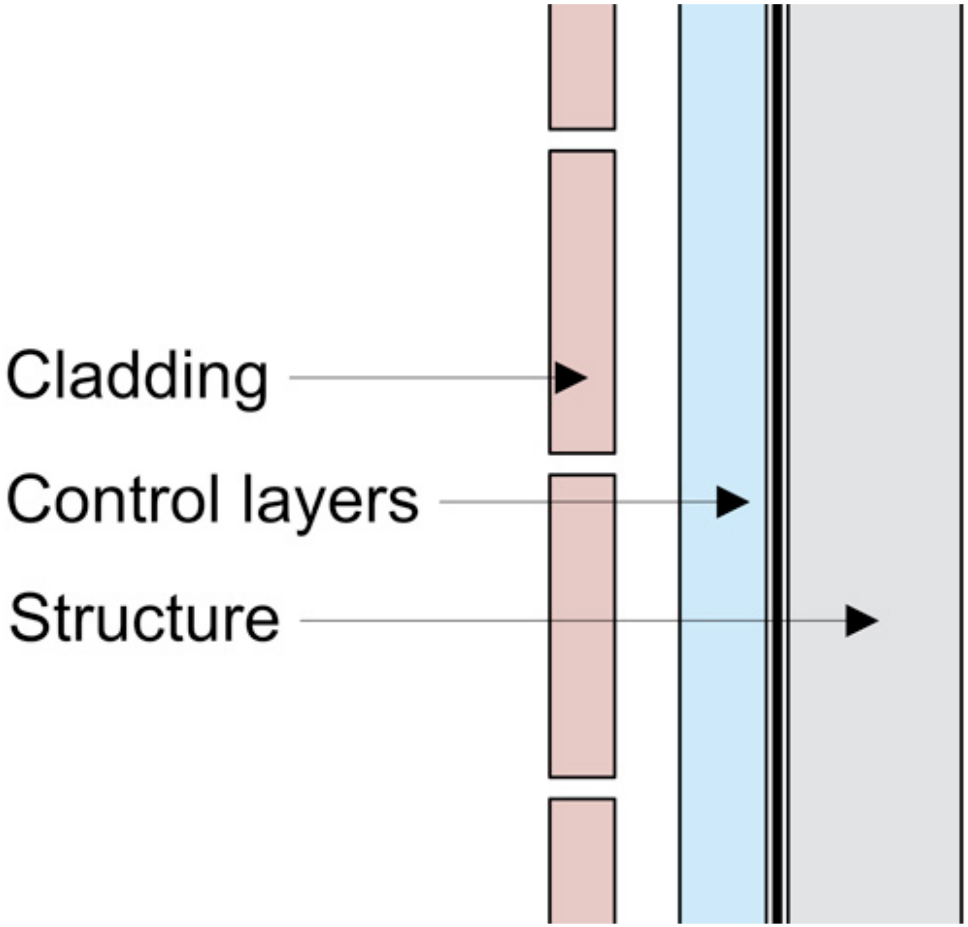
- While the name may change, the concept stays the same!
  - Perfect Wall (Joseph Lstiburek w/ credit to Canadians)
  - PERSIST (Makepeace)
  - REMOTE (Alaskans)
  - PERFORM (Texans)
  - Out-sulation (Industry)
  - Exterior Thermal & Moisture Management System (CCH)

PERFECT H-P ENCLOSURES

- Step 1: Put the structure on the inside
  - Light-frame construction
  - Timber frame
  - Concrete masonry
  - SIP
  - SPS = Solid Panel System (studless)

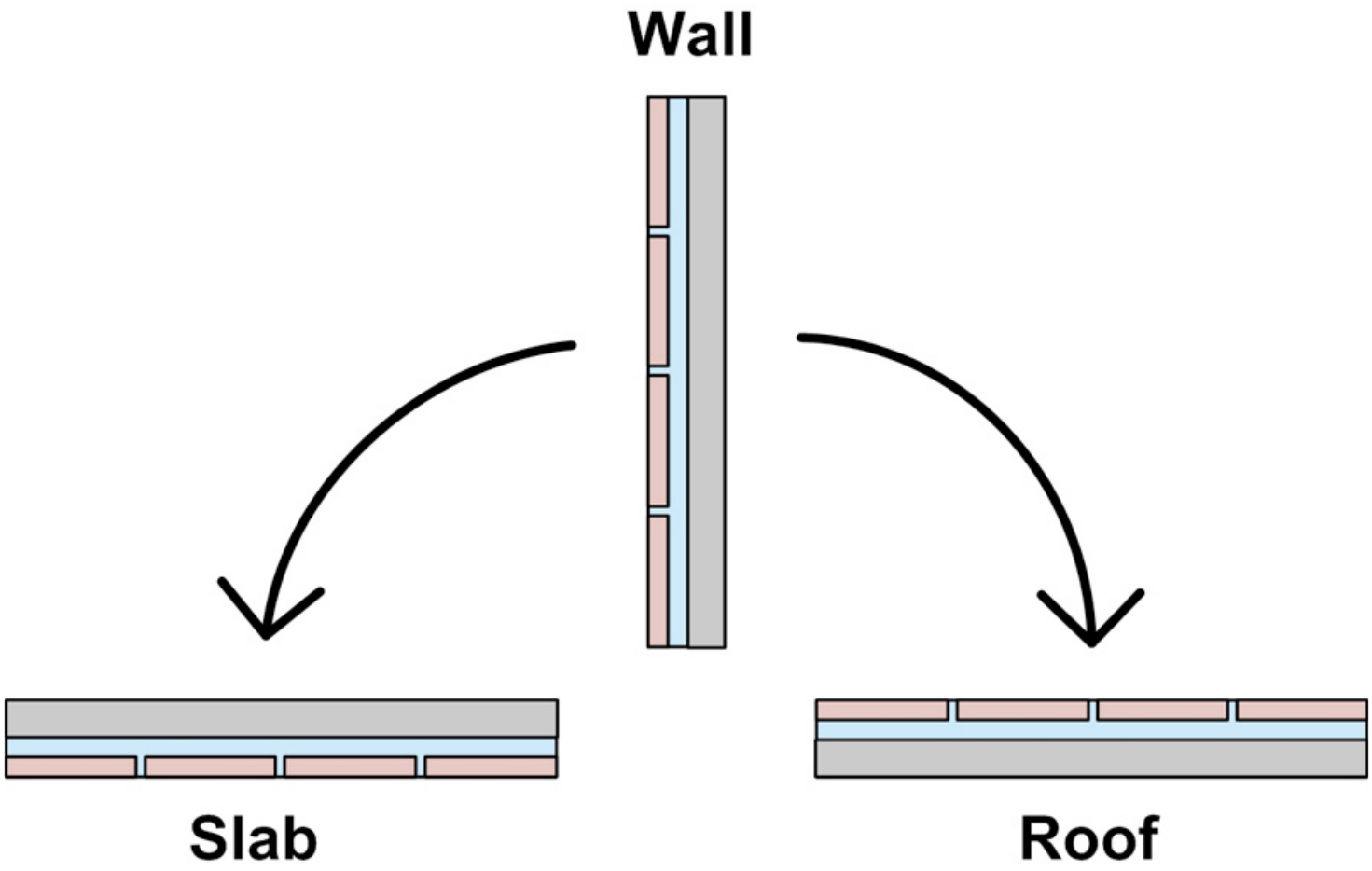
- Step 2: Put the thermal, moisture, and air control layers on the outside.

THE PERFECT WALL (FROM BSC)



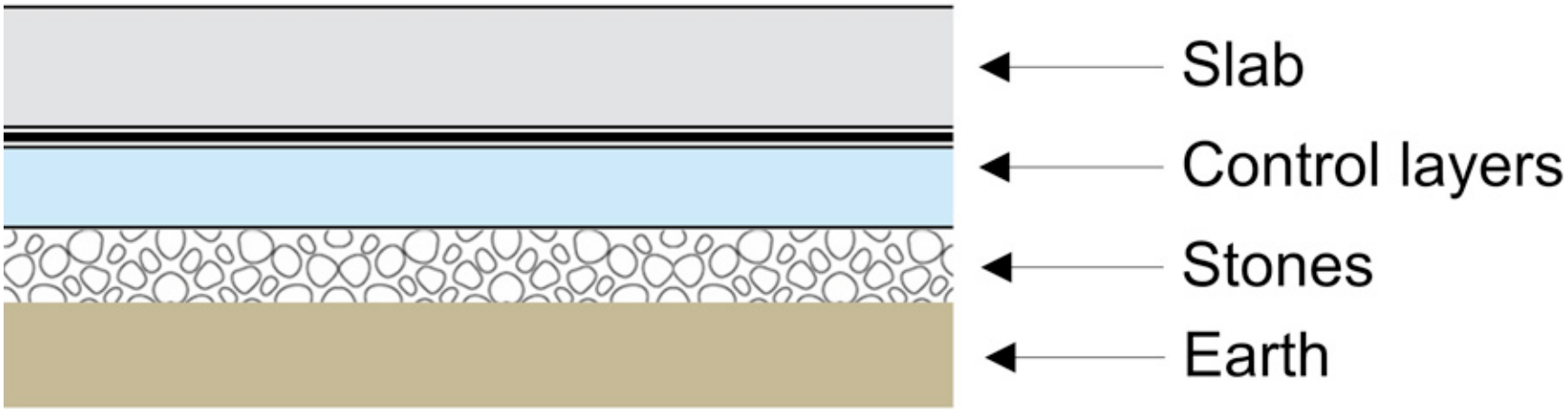
* BSI-001: The Perfect Wall
Joseph Lstiburek
Building Science Corporation

WORKS FOR ROOF & SLAB, TOO!

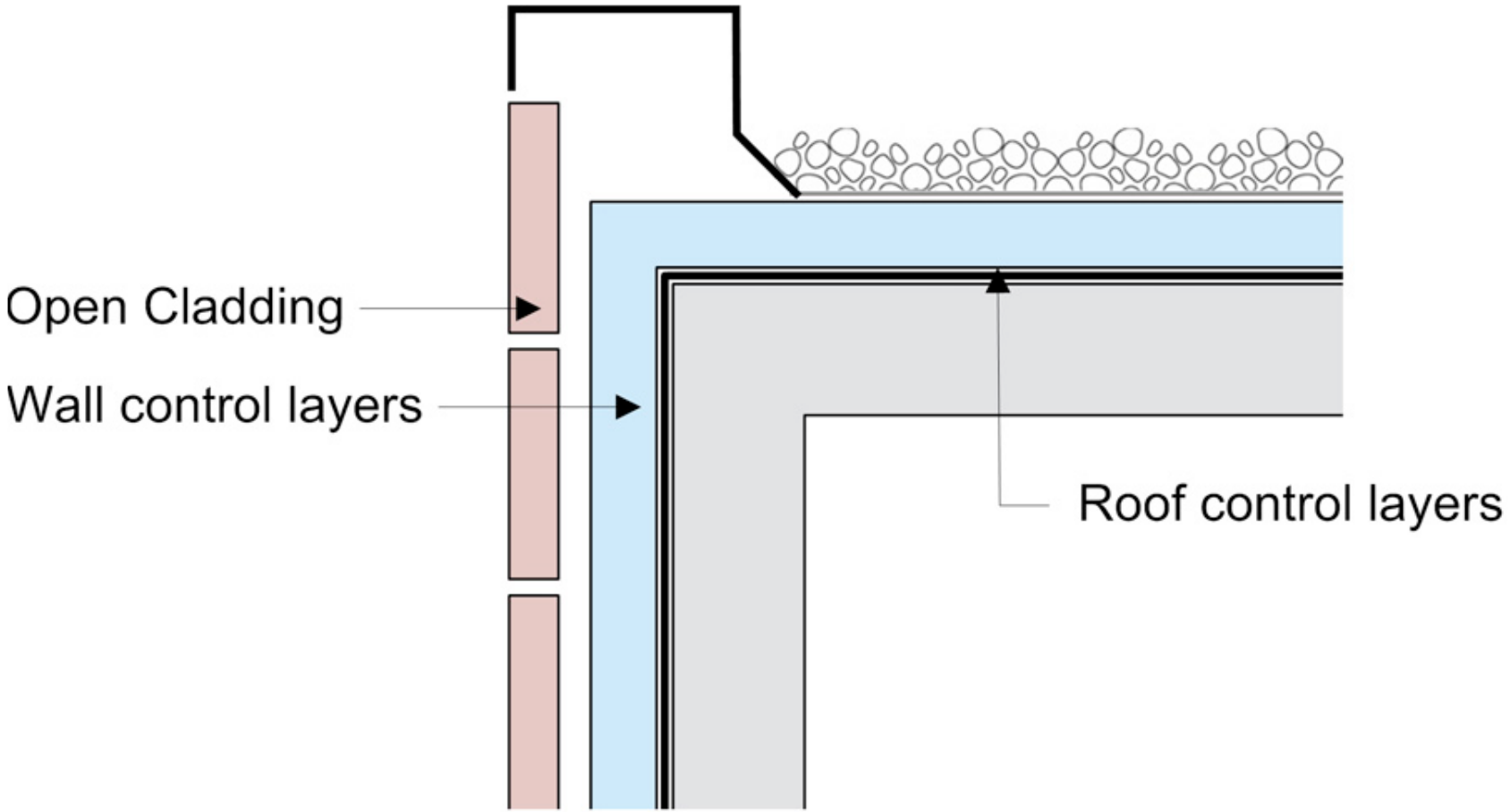


THE PERFECT ROOF

THE PERFECT SLAB



PERFECT CONNECTIONS

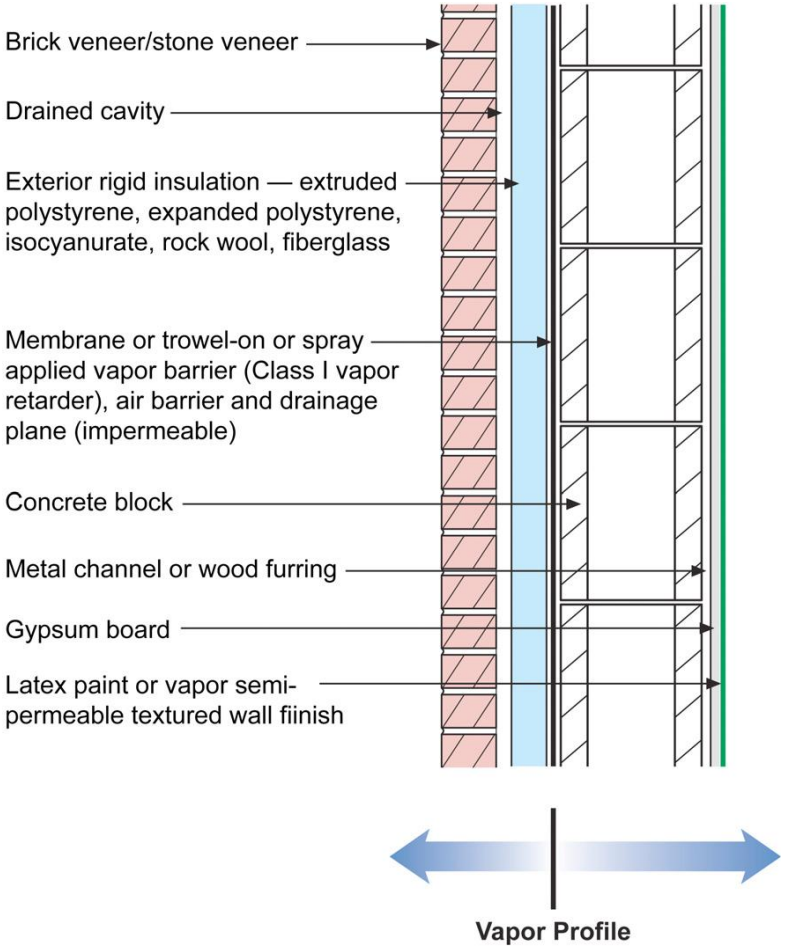


PUTTING THE LAYERS TOGETHER

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

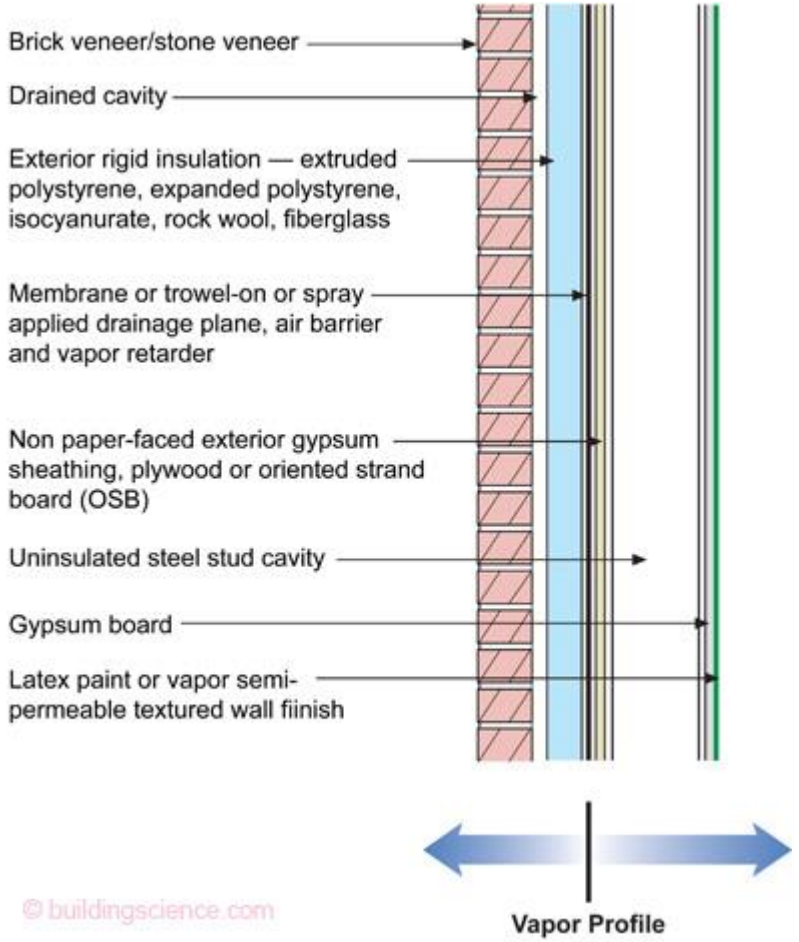
- What you use is important, but the where, how, and when (order/sequence) is critical.
  - However, it can be extremely simple!

THE PERFECT INSTITUTIONAL WALL



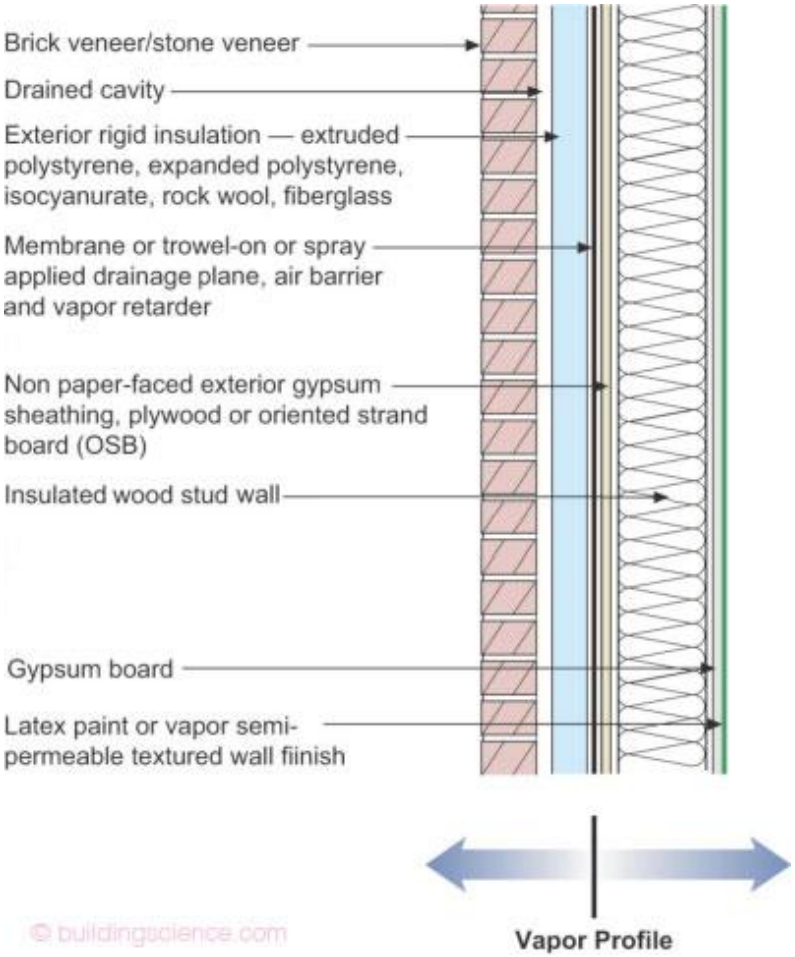
Courtesy of Building Science Corporation

THE PERFECT COMMERCIAL WALL



Courtesy of Building Science Corporation

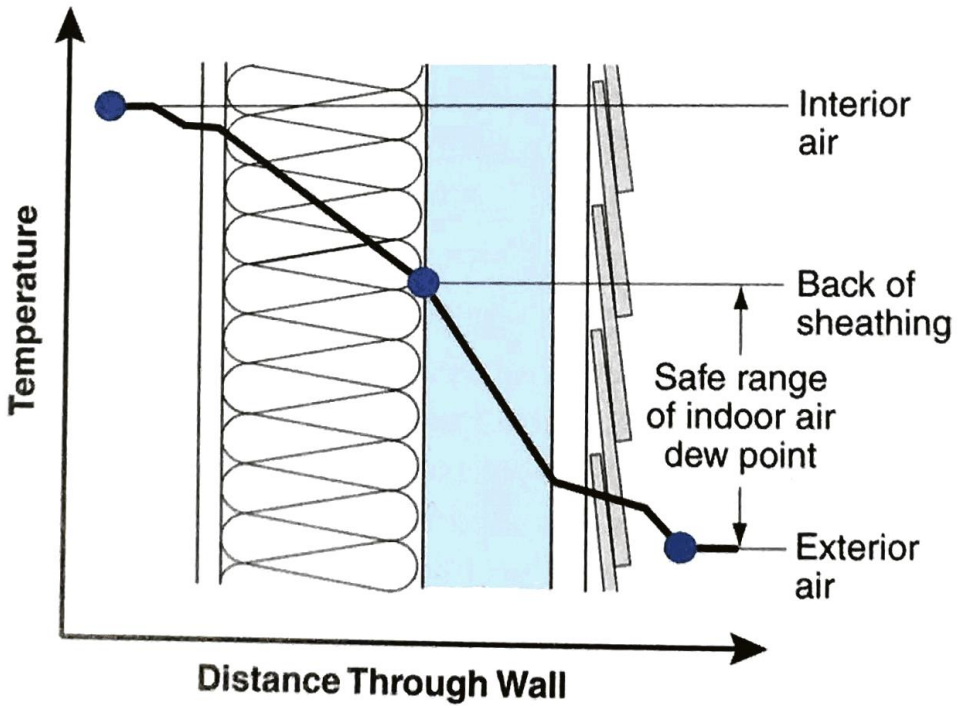
THE PERFECT RESIDENTIAL WALL



Courtesy of Building Science Corporation

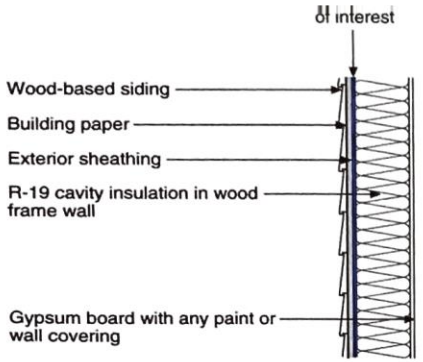
HOW MUCH EXTERIOR INSULATION?

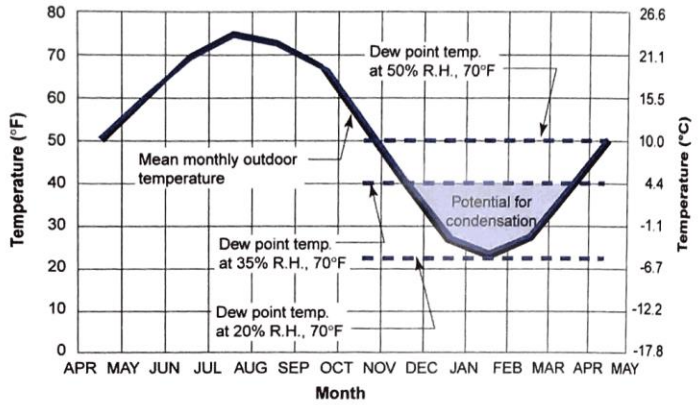
$$T_{back\ of\ sheathing} = T_{interior} - (T_{interior} - T_{exterior}) \frac{R_{batt}}{R_{total}}$$

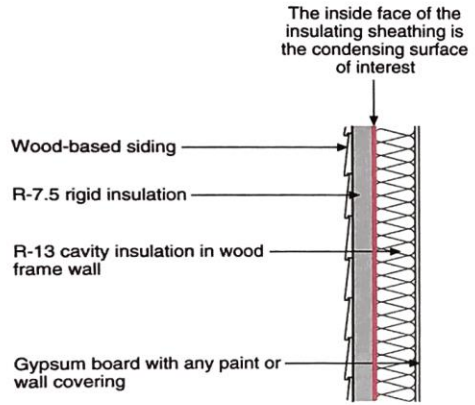


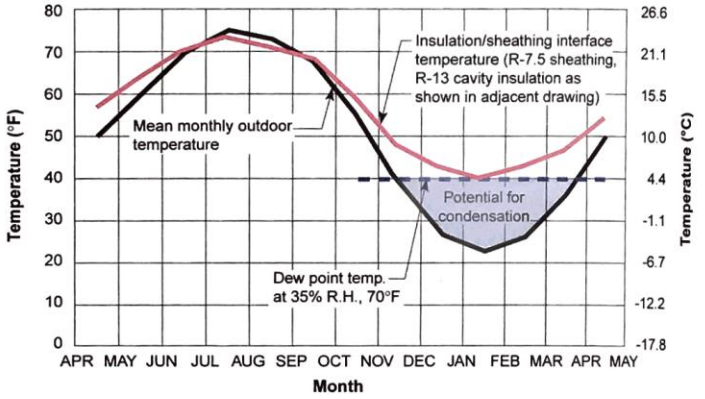
High Performance Enclosures: John Straube, 2012

CONDENSATION POTENTIAL









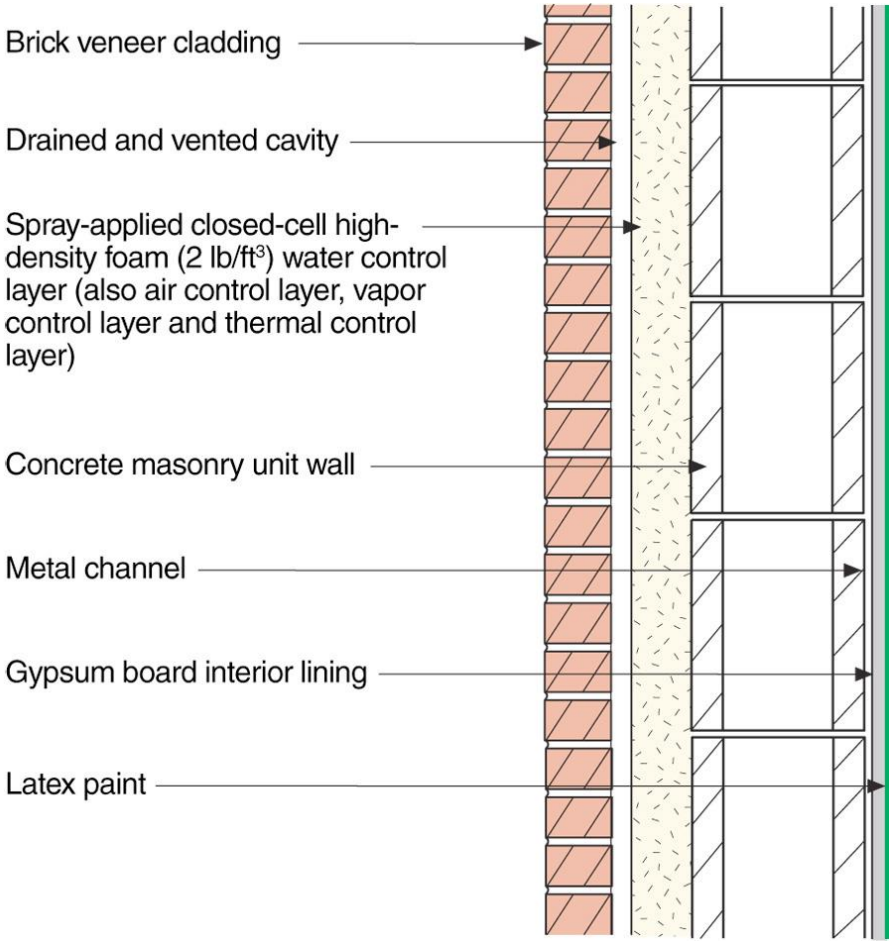
High Performance Enclosures: John Straube, 2012

RATIO OF EXTERIOR TO INTERIOR

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

4 IN 1 CONTROL LAYER



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

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 – 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 – 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).

4. WALL CASE STUDIES

- Desired Outcomes
  - Comfortable
  - Efficient
  - Durable
  - Healthy
  - Resilient
- Desired Characteristics
  - Accessible
  - Easy to build
  - Robust
  - Cost effective

WALL A: EXTENDED PLATE WALL (EPW)

- EPW system developed by the Home Innovation Research Labs and is currently being proposed for adoption in the IRC.
  - 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 (11%)
    - Cost, complexity, and lack of industry-wide training
  - Need a basic option for robust high-performance walls that is flexible for both site-built and panelization

EXTENDED PLATE WALL: SOLUTION

Interior View

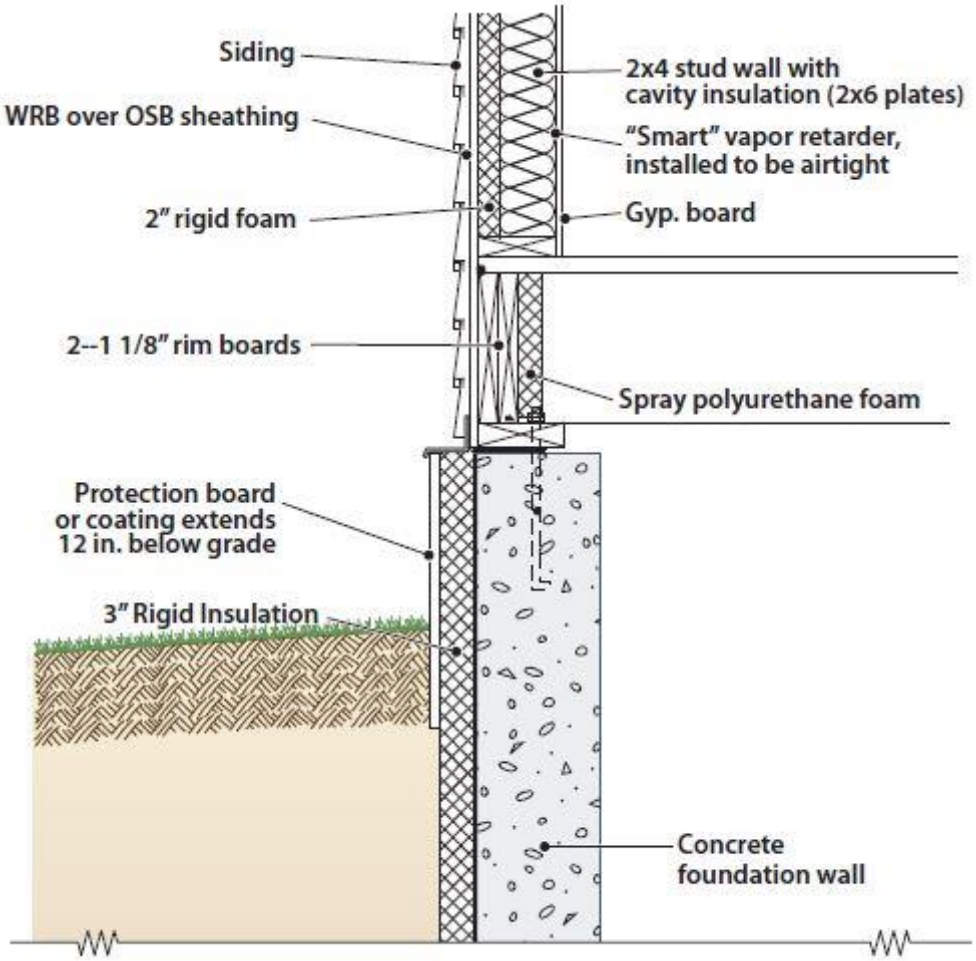
Exterior View

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

EPW: KEY CHARACTERISTICS

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

CONTROL LAYERS – EPB (FROM HIL)



EPW: CONTROL LAYERS

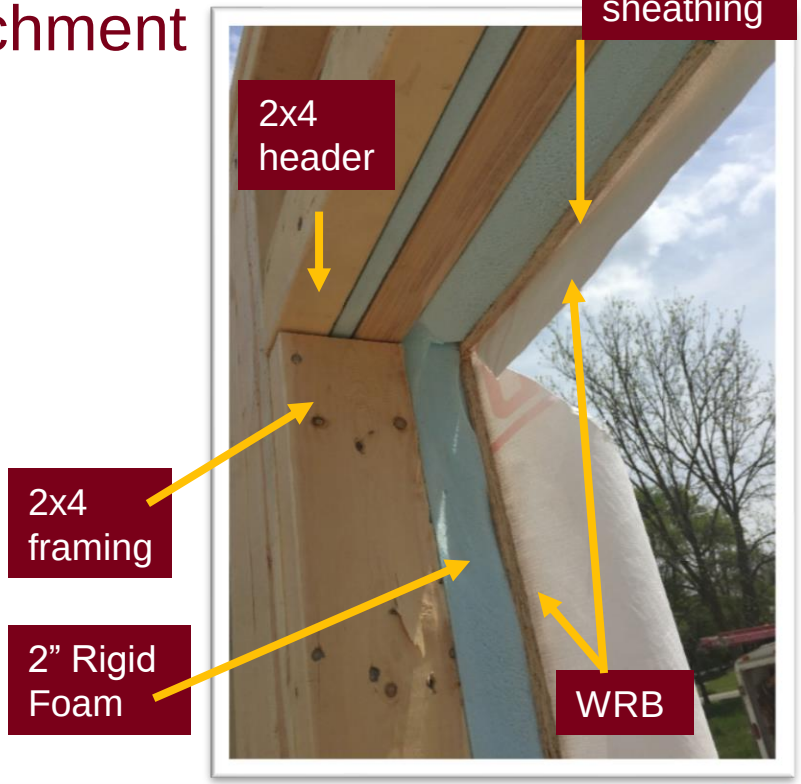
- Water Control Layer
  - WRB, shingle-applied, fastened to OSB sheathing or
  - Treated OSB sheathing (liquid-applied or taped seams)
- Air Control Layer
  - Rigid foam, sealed as described, performs as the air barrier in addition to the vapor barrier or
  - WRB, taped to itself and to transition members
- Thermal Control Layers
  - Rigid foam insulation protects cavity fill insulation
  - Extended plates constitute <5% thermal bridging

EPW: CONTROL LAYERS

- Vapor Control Strategies
  - Rigid foam, sealed with caulk or ccSPF, is a distinct, centrally-located vapor control plane with effective drying to the direction from which the source moisture originated – exterior to the exterior and interior to the interior.
  - Interior vapor retarder recommended in cold climates and buildings with high indoor humidity
    - preferably a kraft-facer or “smart” vapor retarder.

EPW: ADVANTAGES

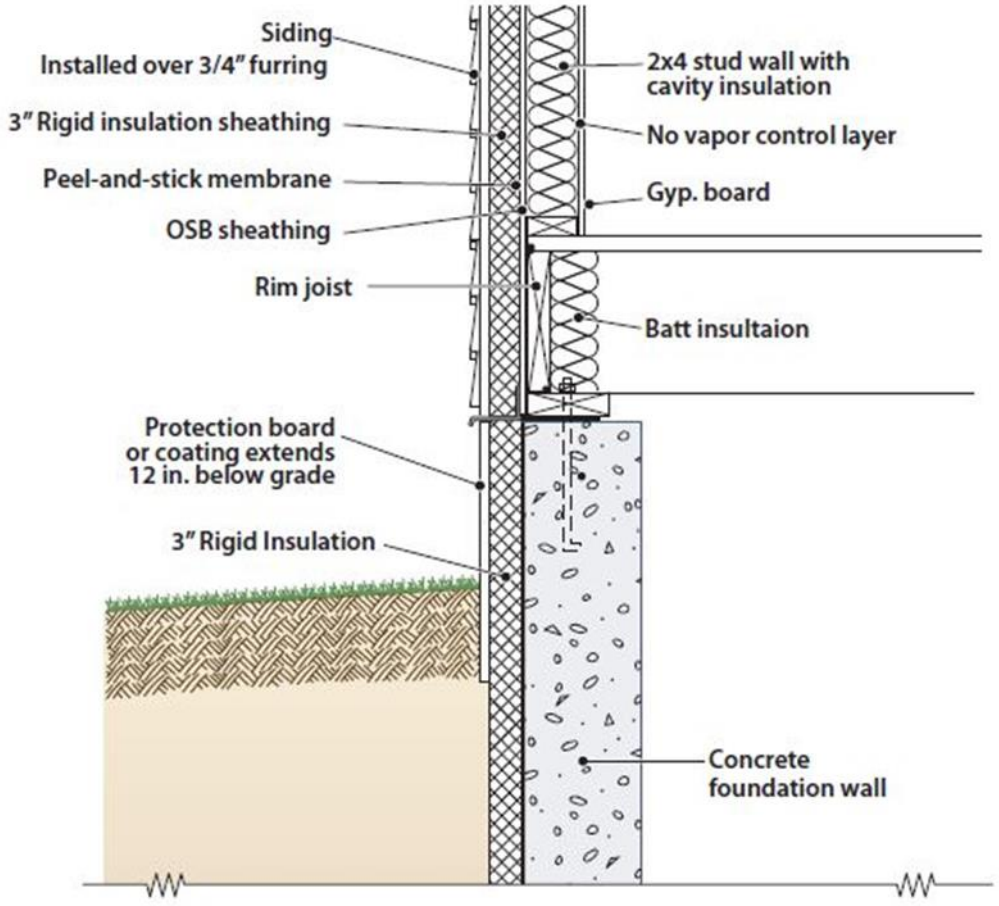
- Standard framing and air sealing techniques
- Relies on extended bottom and double top plates for wood structural panel attachment
- Uses standard nails in a common fastening schedule (3-1/2” @ 3” edge/6” field)
- Exterior OSB allows conventional methods for
  - Drainage plane treatment
  - Window installation
  - Cladding attachment



EPW: ADVANTAGES

- Suitable for use in all climate zones
- Flexible configurations to achieve above-code thermal performance even in CZ 8
- 95% of the wall area is free of thermal bridging
- Estimated cost is $0.50 to $1.00/sf less than a comparable code wall with continuous exterior insulation
- Can be panelized for packaged delivery to the site

WALL B: OPTI-MN (HYBRID) WALL



University of Minnesota's

Team OptiMN

WINS TOP AWARD

In DOE's "Race to Zero"

Student Design Competition

INTRODUCING | The Impact Home

INTRODUCING | Multi-Disciplinary Team

14 Students from Building Science, Construction Management, Business, Marketing, and Sustainable Design

Design, analyze, and present an affordable, resilient, high-performance "Zero Energy Ready Home" as infill new construction for a vacant lot in north Minneapolis

Residential Building Science

Collin Coltman
Matthew Dries
Maria Finsness
Tyler Kitzerow
Frank Peeters
Peter Schneider
Kristel Spiegelberg
Cavan Wagg

Construction Management

Collin Coltman
Jose Aaron Cruz-Salinas
Kyle Holmes
Jackie Larson
Peter Schneider

Business & Marketing Education

Aaron Hanson

Master of Science Sustainable Design & Masters in Architecture

Laurel Johnston

Bioproducts & Biosystems Science, Engineering, & Management

Maria Fernanda Laguarda Mallo (PhD candidate)

PERFORMANCE GOALS | Site in DOE Climate Zone 6

Durable & Long-Lasting

ZERO ENERGY READY HOME
U.S. DEPARTMENT OF ENERGY

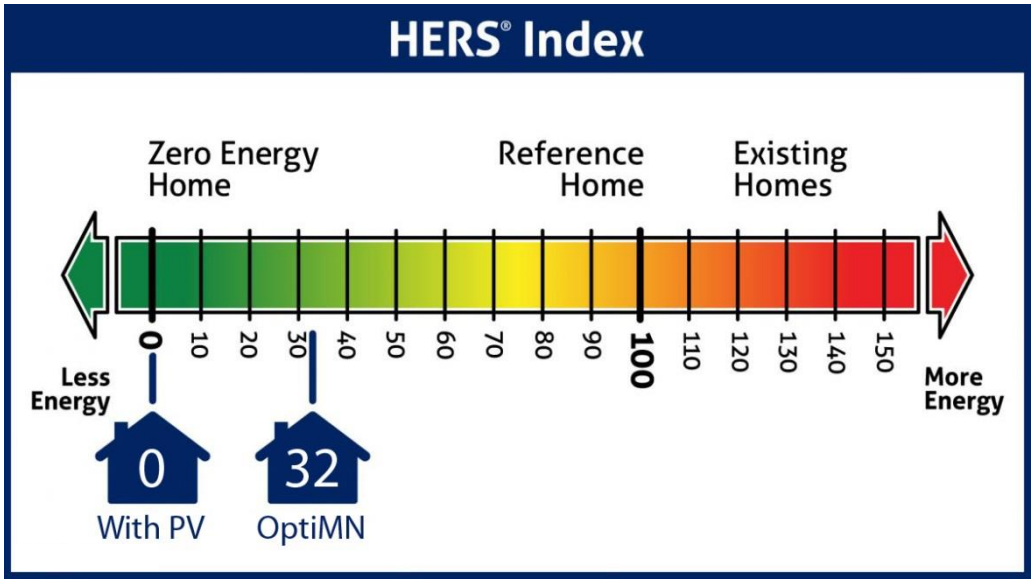
Fortified Home

FORTIFIED HOME

Indoor Air Quality

EPA Indoor airPLUS
QUALIFIED HOMES

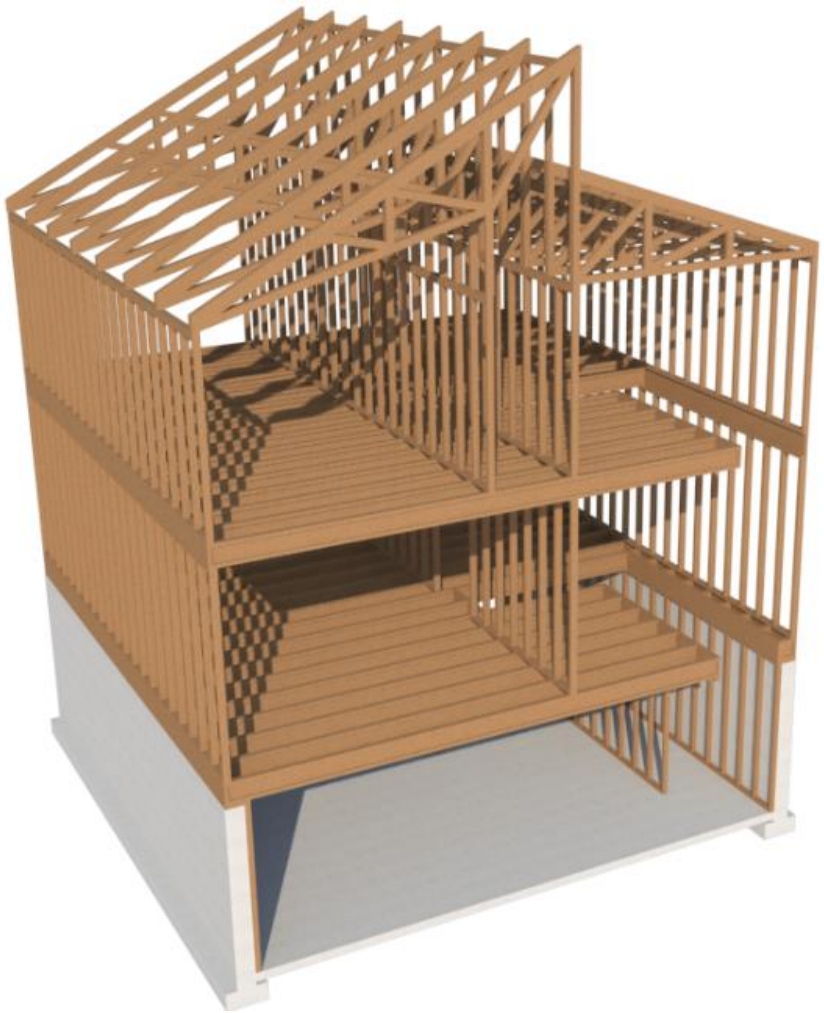
Energy Efficient | Zero Energy Ready

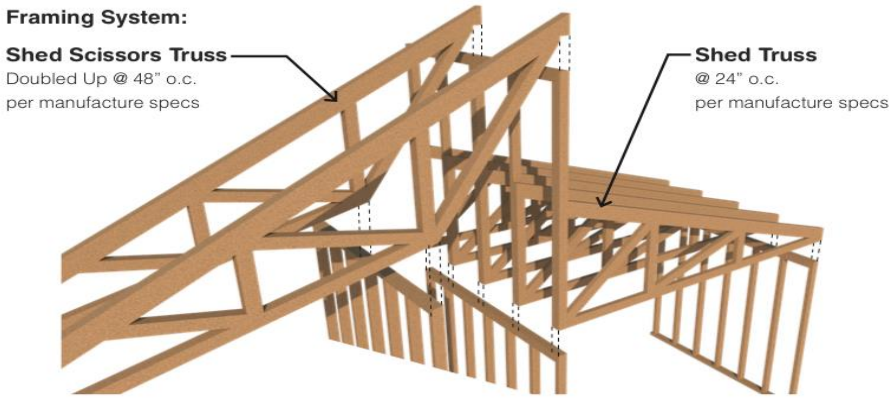


Water Stewardship

WaterSense
Meets EPA Criteria
SM

CONSTRUCTABILITY





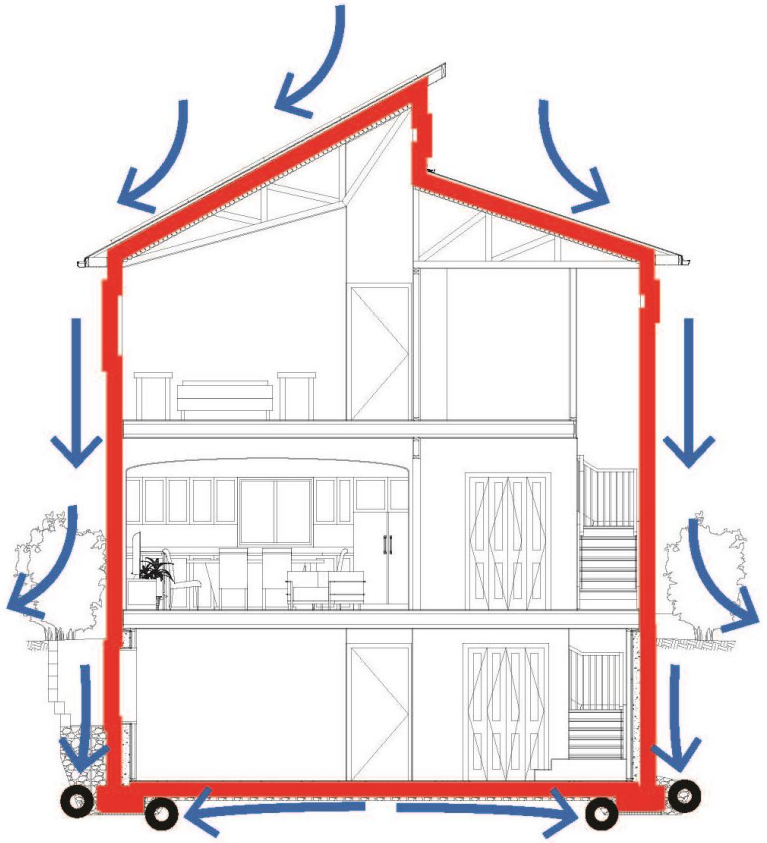
Approachable and Appropriate Construction Materials and Methods

- Simplified design and shape
- Based on traditional construction materials and techniques
- Simplified ducting and hot water systems

Heat Management

Air Management

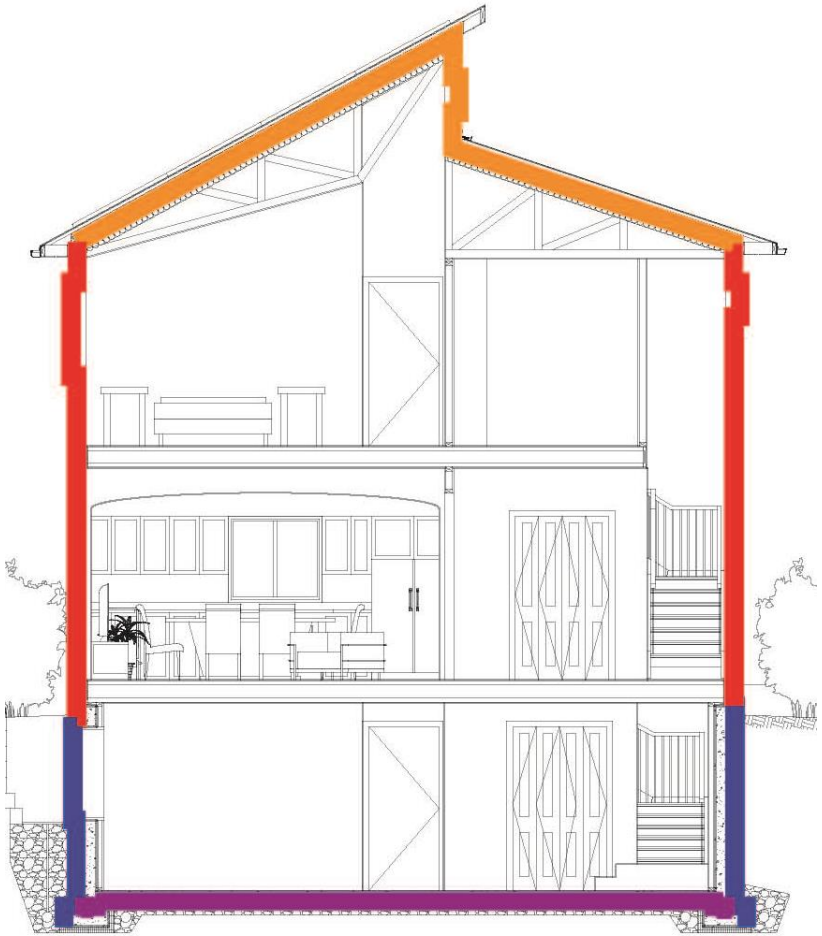
Moisture Management



ENCLOSURE DESIGN | 4 Control Layers

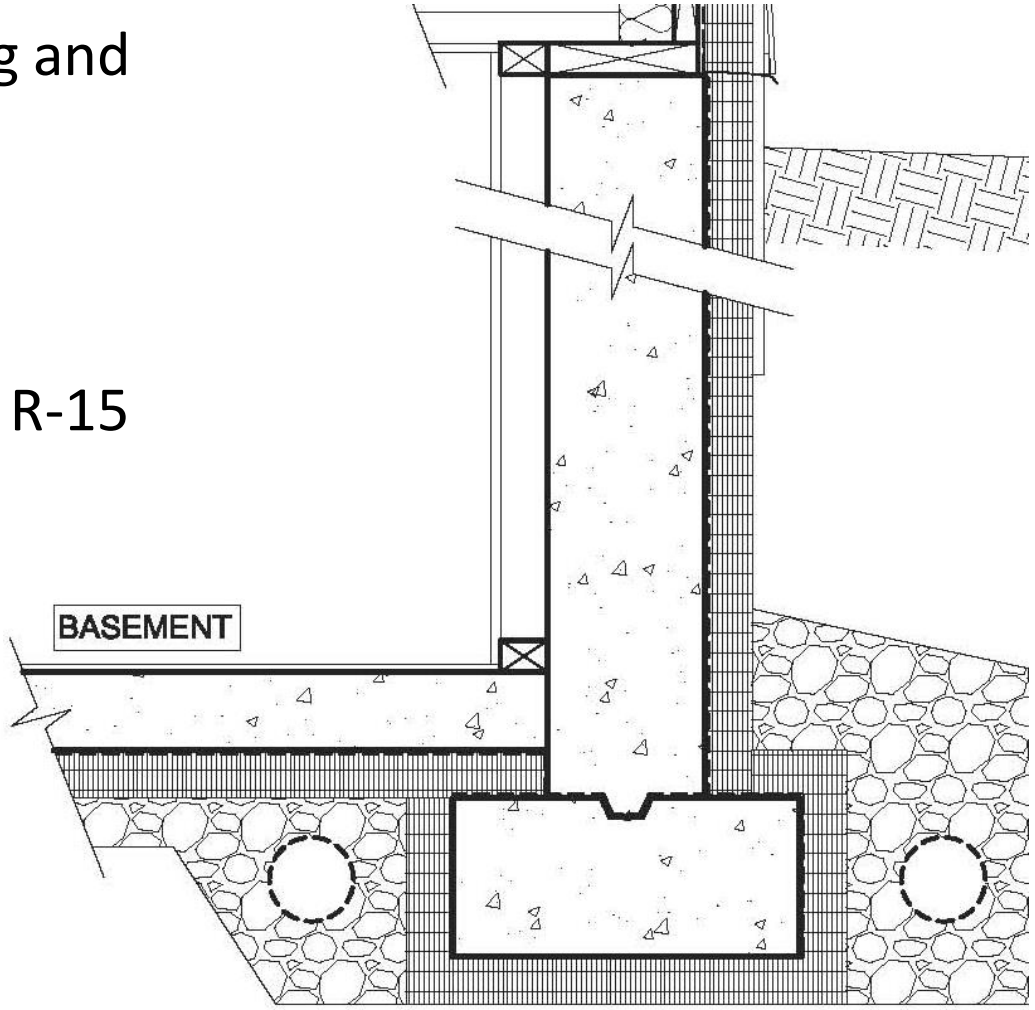
- **Thermal** insulation to retard heat flow
- **Water** control membrane to prevent wetting of moisture sensitive materials
- **Air** barrier to stop unwanted heat and moisture flow
- **Vapor** retarder strategy to prevent wetting, yet allow drying

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



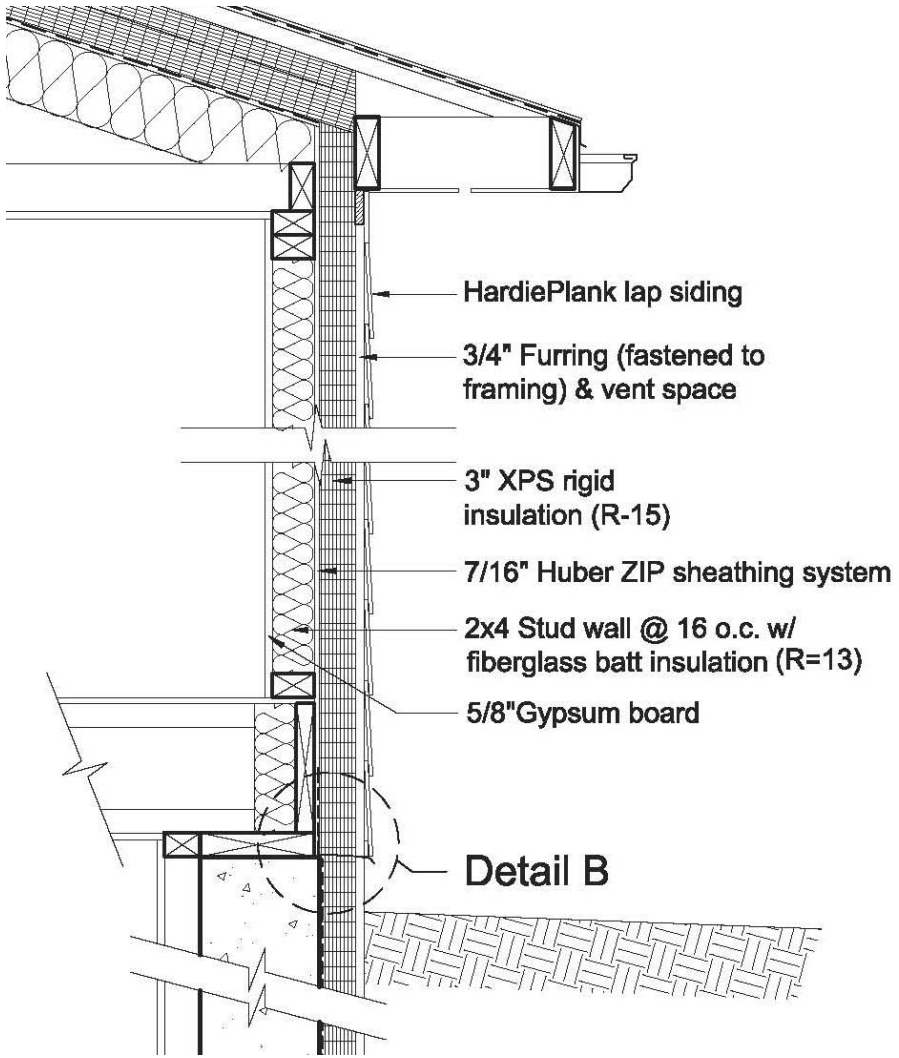
FOUNDATION STRATEGY | Airtight, Dry, & Warm

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



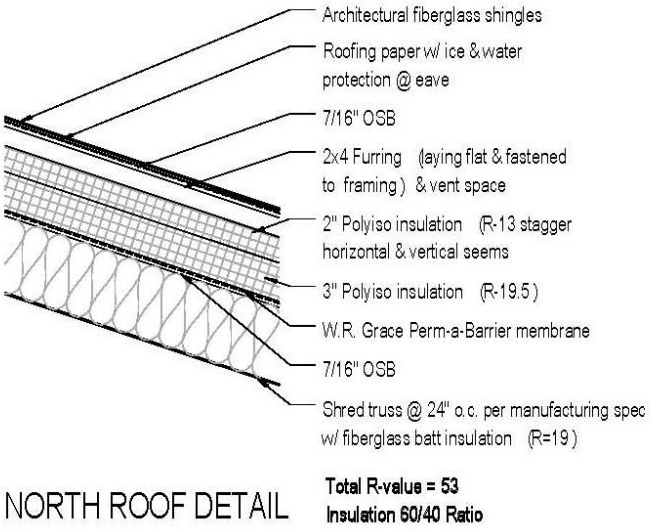
HYBRID WALL STRATEGY | Robust & Easy to Construct

- 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



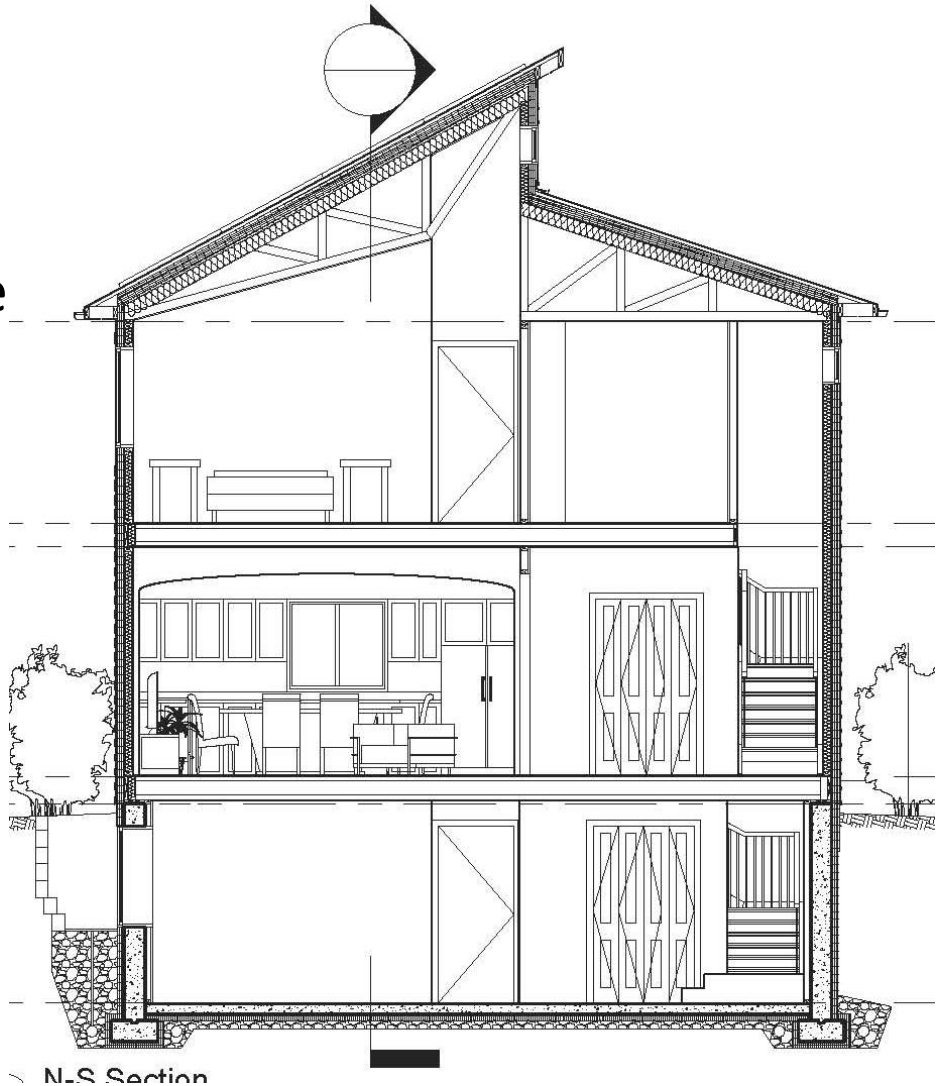
HYBRID ROOF STRATEGY | Adds Flexible Space & Robust

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



NORTH ROOF DETAIL

Total R-value = 53
Insulation 60/40 Ratio

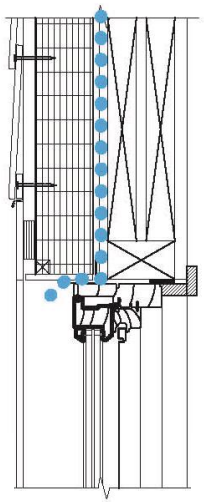


N-S Section

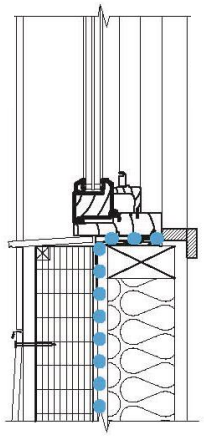
FENESTRATION STRATEGY | Efficient & Affordable

- Used high-performance double-pane, low emissivity, gas filled windows
  - U-value = .27
  - SHGC = .20
- Cost less than triple or quad pane and still achieved our performance goals

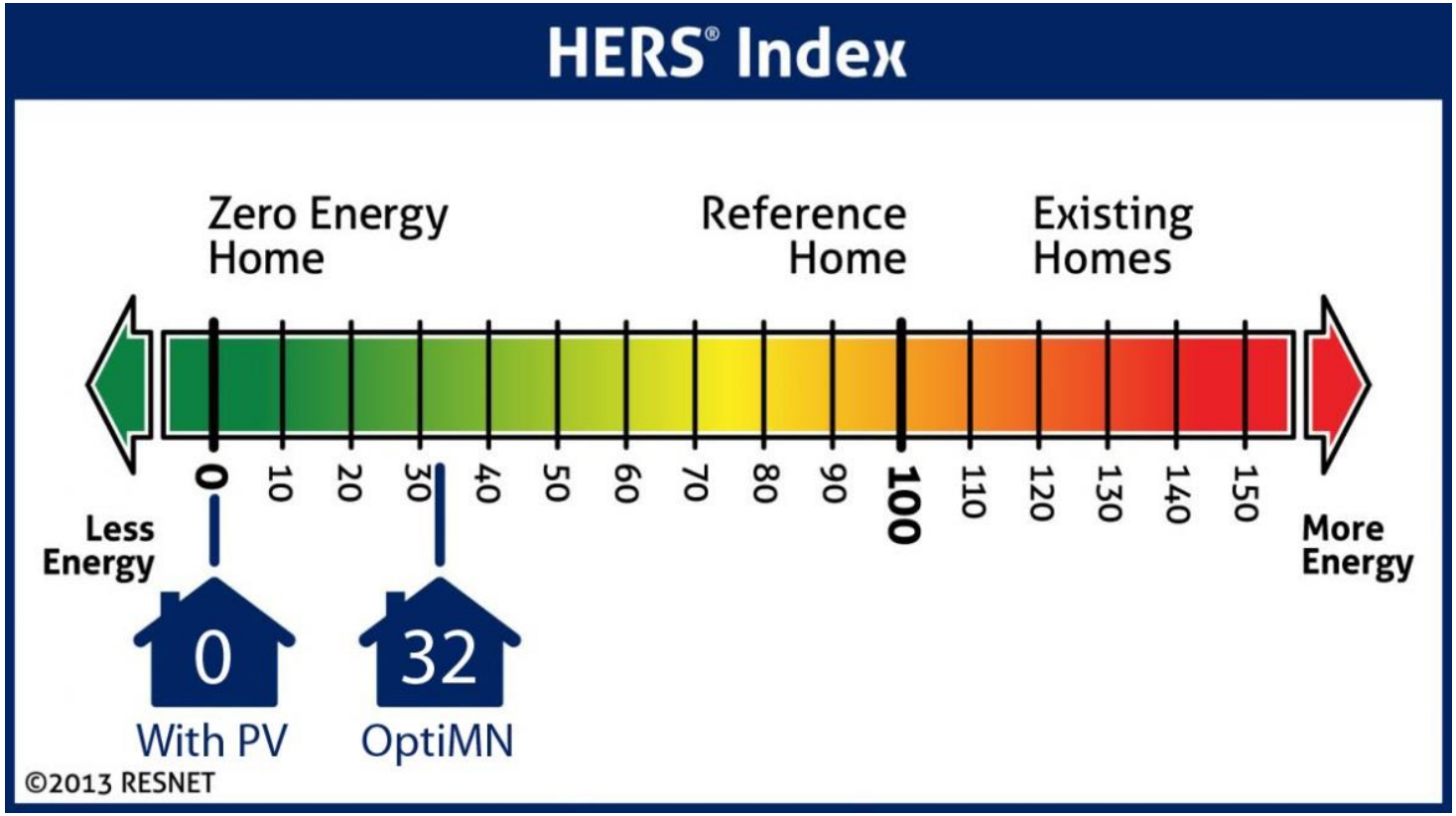
OUTSIDE



INSIDE



PERFORMANCE



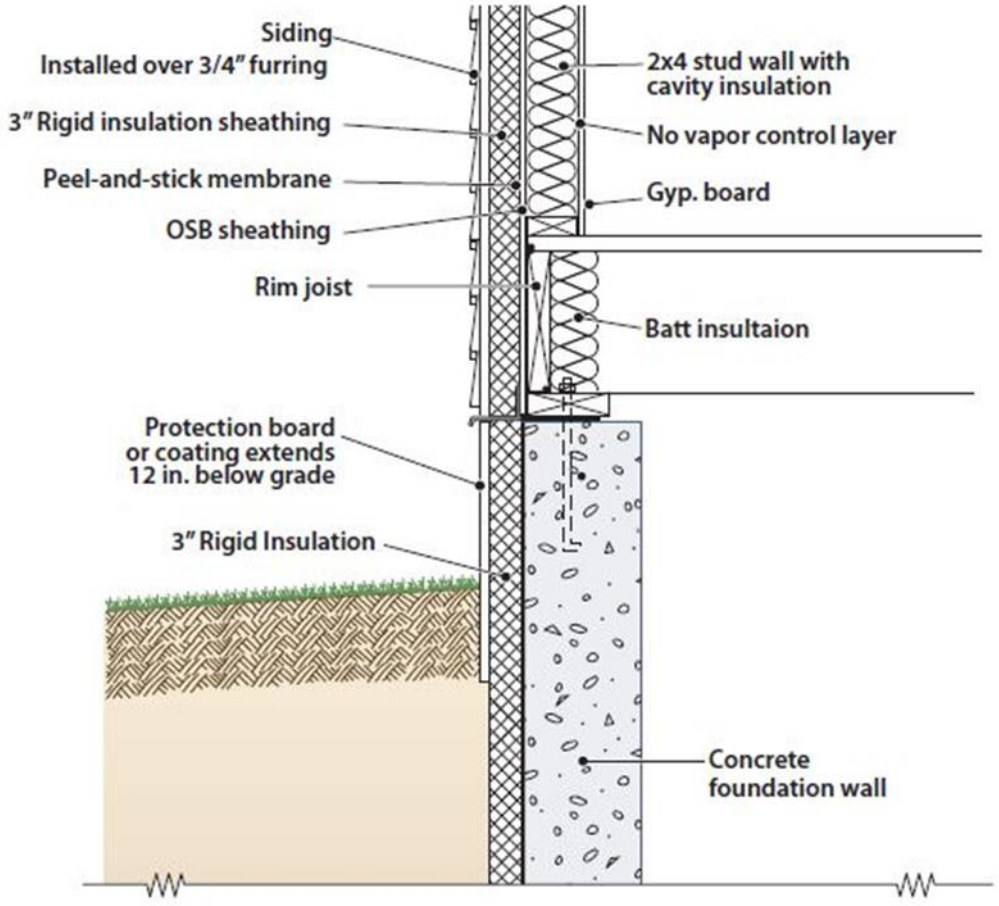
Heating, cooling, and water heating costs is approximately **$420 / year**

It is so simple – the Team OptiMN "IMPACT Home" …

… Looks Good, Works Great, AND is Affordable, too!

Which means anyone can build a Zero Energy Ready Home.

OPTI-MN HYBRID WALL



REVIEW OF OPTI-MN 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 SYSTEM

- Building America funded project to validate:
  - a new enclosure technology
  - delivered by a single enclosure contractor
- The project will measure and compare:
  - performance (energy, moisture, air)
  - constructability and quality control
  - costs (materials, labor, etc.)
- Demonstrate market acceptance
  - focus on affordable housing

SOLID PANEL STRUCTURAL SYSTEM

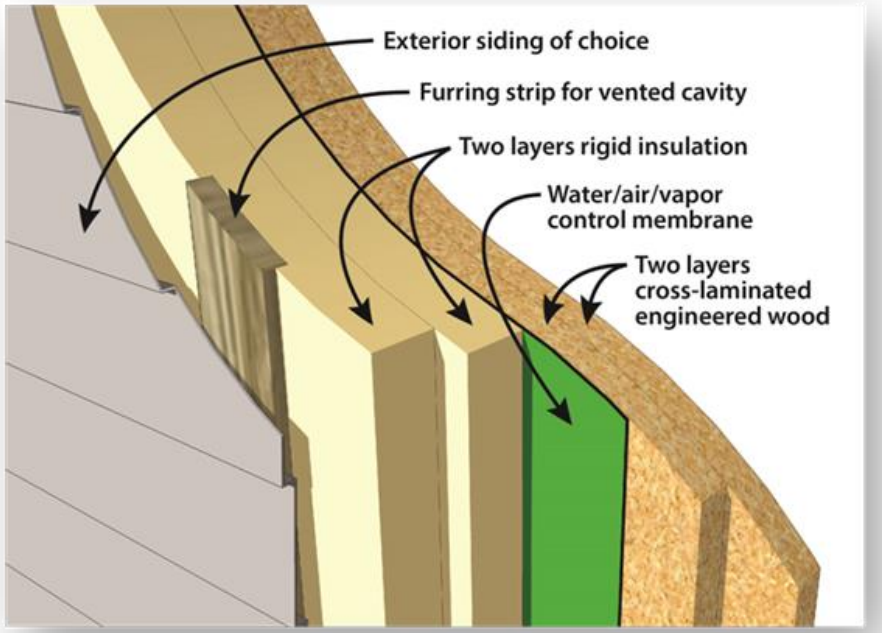
- Research hypotheses are straightforward:
  - This innovative building enclosure system can outperform conventional wood-frame construction at lower cost.
  - This innovative building delivery system will ensure better QA/QC.
  - This optimized whole building system can deliver cost-effective Zero Energy Ready Homes for affordable homes.

BENEFITS OF “PERFECT WALL”

- Structure is kept warm/dry
- Control layers are simplified
- Continuous exterior insulation
- Critical control layers and materials are protected
- Back-ventilated cladding
- Sensitive materials can dry
- Can be used in any climate

BENEFITS OF "SOLID PANEL SYSTEM"

- Reduces costs of the "Perfect Wall"
- Simplifies application of exterior control layers
- Requires less labor and less skill
- Speeds enclosure time (esp. dry-in)
- Stronger with enhanced protection (resilient)



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

One of seven homes built in St. Paul Frogtown in 2014.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REALTY
651-998-0998


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DEBUSSY
BEETHOVEN
HAYDN
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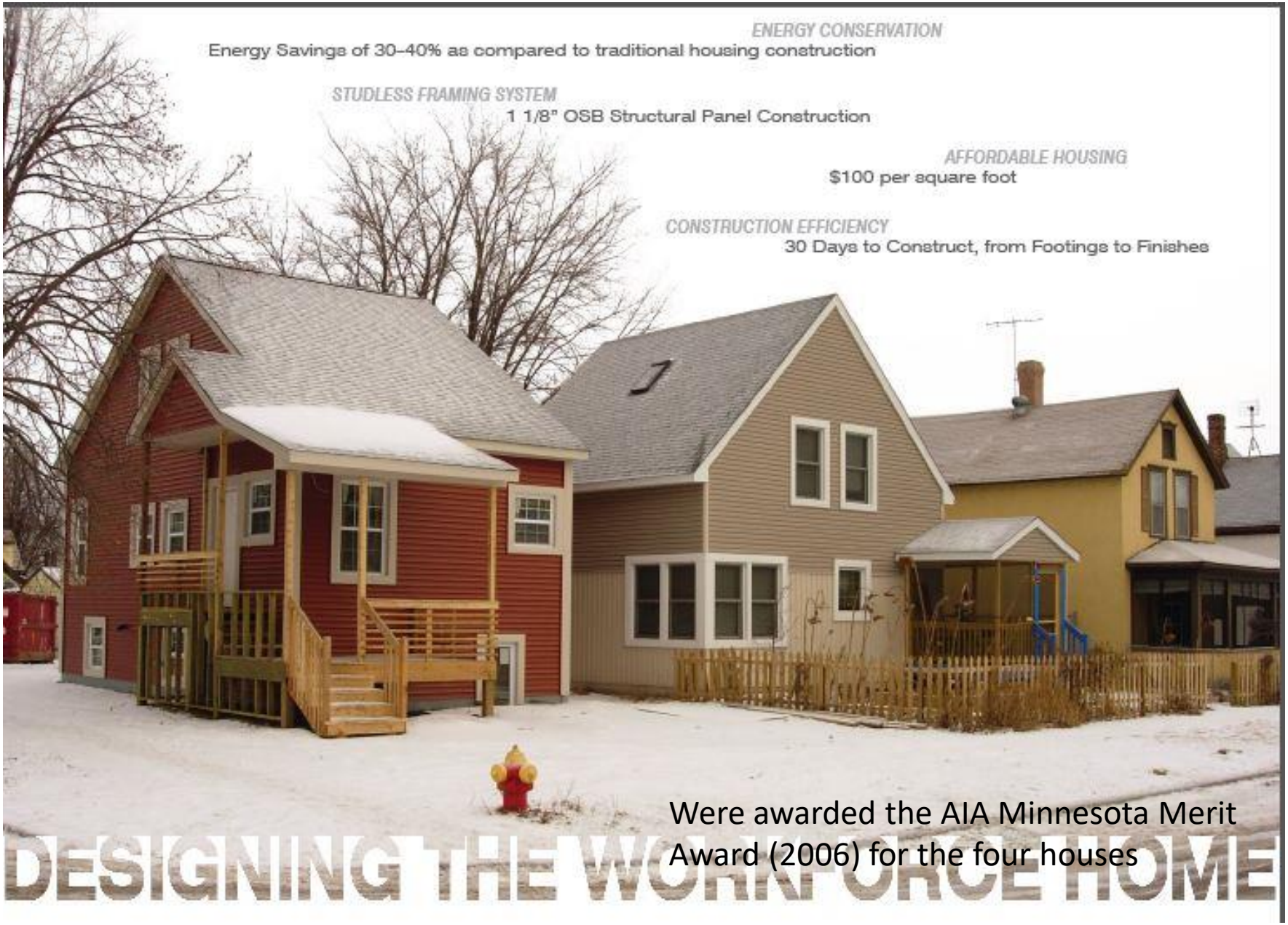
REVIEW OF SPS CONTROL LAYERS

- 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

WALL COMPARISON – COSTS

- Work in progress…
  - The Opti-MN costs more than the code minimum and the TC-HFH Energy Star base wall.
  - The SPS system costs less than the Opti-MN
    - Primarily due to framing material and labor savings.
  - We believe SPS will approach the same cost as the Energy Star, with a couple of caveats.
    - There is an upfront engineering cost premium.
    - There is a learning curve to capture labor savings.
    - Its superior airtightness demands a MUA system.



Were awarded the AIA Minnesota Merit Award (2006) for the four houses

4 homes built
between 2001-2005:
3 in St. Paul
1 in Minneapolis


Researching New Construction Technology
Project 20-20
A Joint Research Project
Developing housing that is Durable, Healthy, Energy efficient, Good for the environment and Truly affordable
Sponsored by:
Financed by:
651-948-2009

ACE
Perm-A-B
GRAC
Perm


A/C
Dryer
Elec
Service
Hose
Bib


4 11:53AM


STERLING
4 11:54AM


STERLING
4 11:59AM


STERLING
4 12:02PM


L S
722 2345


GRACE
Bituthene
GRACE
Perm-A-Barrier
GRACE VYCOR PLUS
GRACE VYCOR


GRACE
Bituthene


METROPOLITAN

SPS SYSTEM RECAP

- Foundation = normal
- Floor deck = mostly normal
- Enclosure (walls & roof) = 1 to 2 days w/ crane
  - Dried-in & Secure = 3 to 5 days
    - walls = primer, membrane windows, & insulation
    - roof = papered & shingled
- Interior framing & finishing = mostly normal
  - knock-down finish for exterior walls
  - electrical integrated in the baseboard and trim

SPS SYSTEM SUMMARY

- Pros
  - Quick erection to dried-in & secured
  - Can use lower-skilled labor
  - Extremely robust
  - Significant strength advantages, but still testing?
- Cons
  - Certain design limitations until system is validated
  - Current upfront engineering costs

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

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

FINAL NOTES & THOUGHTS

- High performance homes need some new partners:
  - Home Energy Raters
  - Home Performance Consultants
  - Home Performance Programs
    - government
    - utilities
    - public/private
    - other

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

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CAD Files
Case Studies
Image Gallery
References

Attic Knee Walls

Please Register or Login to Provide Feedback.

Scope | Description | Ensuring Success | Climate | Training | CAD | Compliance | More Info.

Scope

Fully Aligned Air Barrier

A. Install a top and bottom plate or blocking at the top and bottom of all knee wall cavities.
B. Back attic knee walls with a rigid air barrier or other supporting material to prevent insulation from sagging and create a continuous thermal barrier*
C. Seal all seams, gaps, and holes of the air barrier with caulk or foam.
D. Install insulation without misalignments, compressions, gaps, or voids in all knee wall cavities.

* ENERGY STAR recommends using a rigid air barrier, but it is not a requirement.

Notes:

An air barrier is defined as any durable solid material that blocks air flow between conditioned space and unconditioned space, including necessary sealing to block excessive air flow at edges and seams

diameter unless otherwise indicated by the manufacturer. Flexible air barriers shall not be made of kraft

MOBILE FIELD KIT

The Building America Field Kit allows you to save items to your profile for review or use on-site.

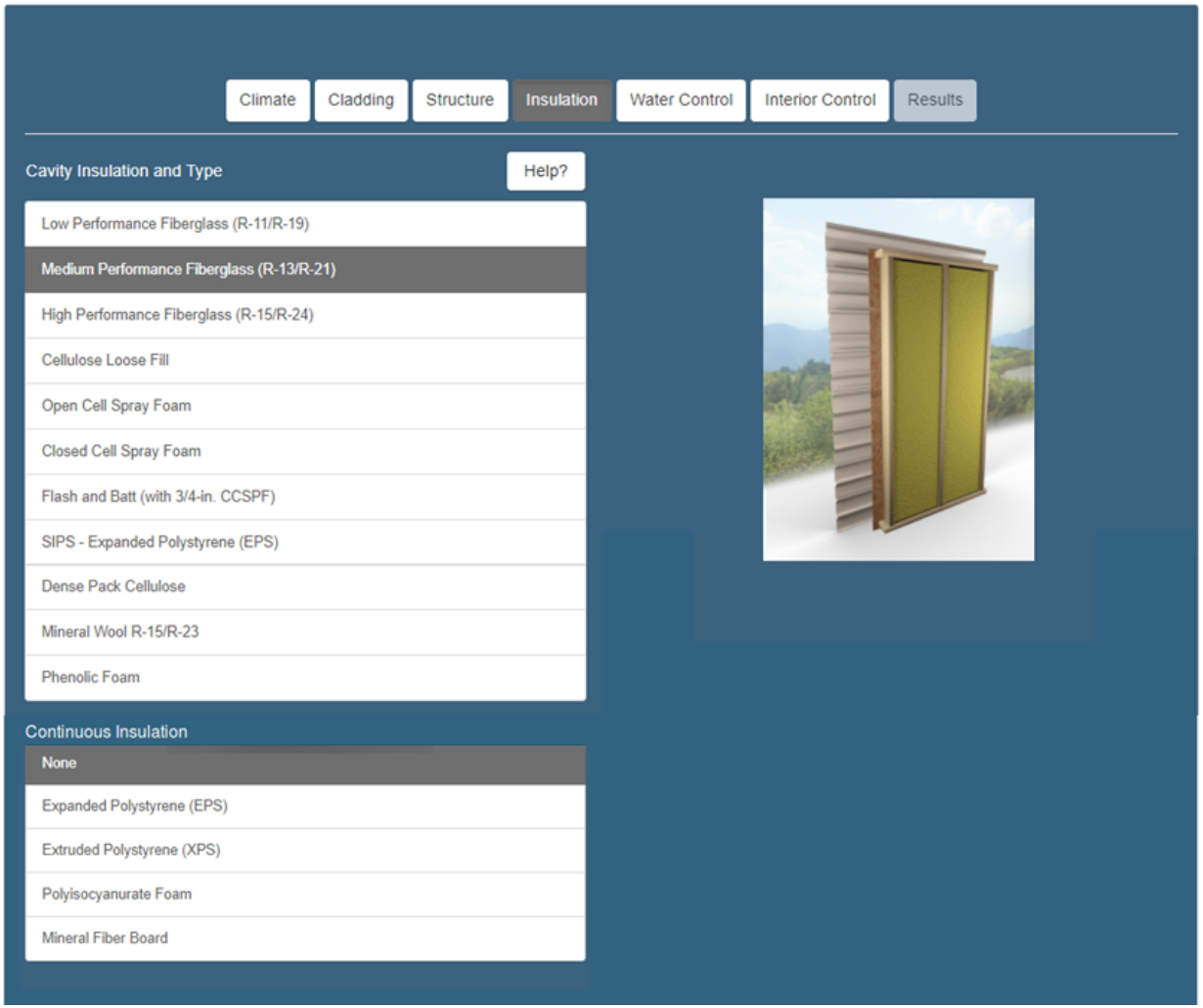
Sign Up

or

Log In

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

RESOURCES FOR H-P WALLS

- BSI-039: The Five Things
  - Joseph Lstiburek
- BSI-028: Energy Flow Across the Enclosure
  - Joseph Lstiburek
- Building Science for Building Enclosures
  - John Straube & Eric Burnett (2005)
- High-Performance Enclosures
  - John Straube (2012)
- Moisture Control Guidance for Buildings
  - U.S. EPA (2013)

RESOURCES FOR H-P WALLS

- BSI-001: The Perfect Wall
  - Joe Lstiburek, 2010
- BSI-090: Joseph Haydn Does the Perfect Wall
  - Joe Lstiburek, 2015
- Builder's Guide to Continuous Insulation
  - Peter Baker & Joseph Lstiburek (2014)
- Getting Enclosures Right in ZERH
  - Joe Lsitburek, 2016
  - http://energy.gov/eere/buildings/doe-zero-energy-ready-home-resources

RESOURCES FOR H-P WALLS

- Building America Solution Center
  - https://basc.pnnl.gov/code-compliance/continuous-insulation-%E2%80%93-claddingfurring-attachment-code-compliance-brief
- Building America Measure Guideline
  - https://www1.eere.energy.gov/buildings/publications/pdfs/building_america/incorporating-thick-layers-exterior-insulation.pdf

- Discussion & Questions

Contact Information

Patrick H. Huelman
203 Kaufert Lab; 2004 Folwell Ave.
St. Paul, MN 55108
612-624-1286
phuelman@umn.edu

SO WHAT ABOUT EXISTING HOMES?

- Exterior insulation provides a more robust approach to:
  - maximize insulation continuity,
  - improve water management,
  - enhance air tightness, and
  - reduce condensation potential.
- You can have your cake and eat it, too!
  - increase energy efficiency
  - while enhancing building durability

APPLICATION TO RETROFIT

- Moving Exterior Insulation to Existing Homes
  - Potential application to existing homes
  - Most work can be completed from the outside
  - However, you must take care of mechanicals
    - sealed combustion
    - mechanical ventilation
    - pressure management
  - Current focus on 1-1/2 story houses

APPLICATION TO RETROFIT

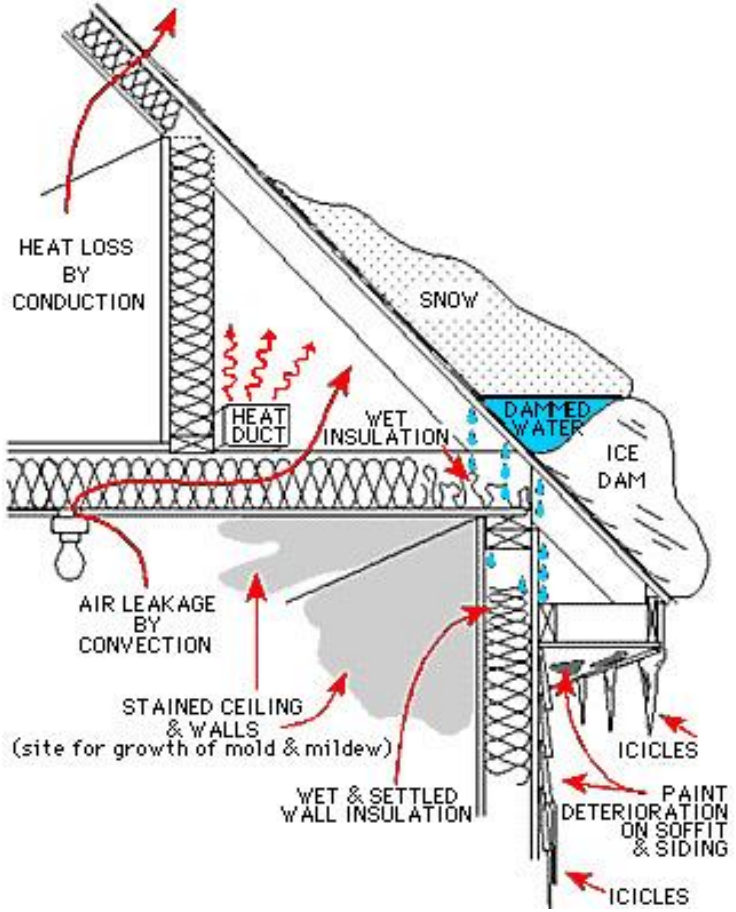
- Low Hanging Fruit
  - Simple house shapes with limited overhangs
  - Homes with good exterior access
    - detached garages with limited patios and decks
  - Homes with nice interior finishes
  - Homes in need of
    - siding, roof, and windows

BEST OF NORTHERN*STAR*

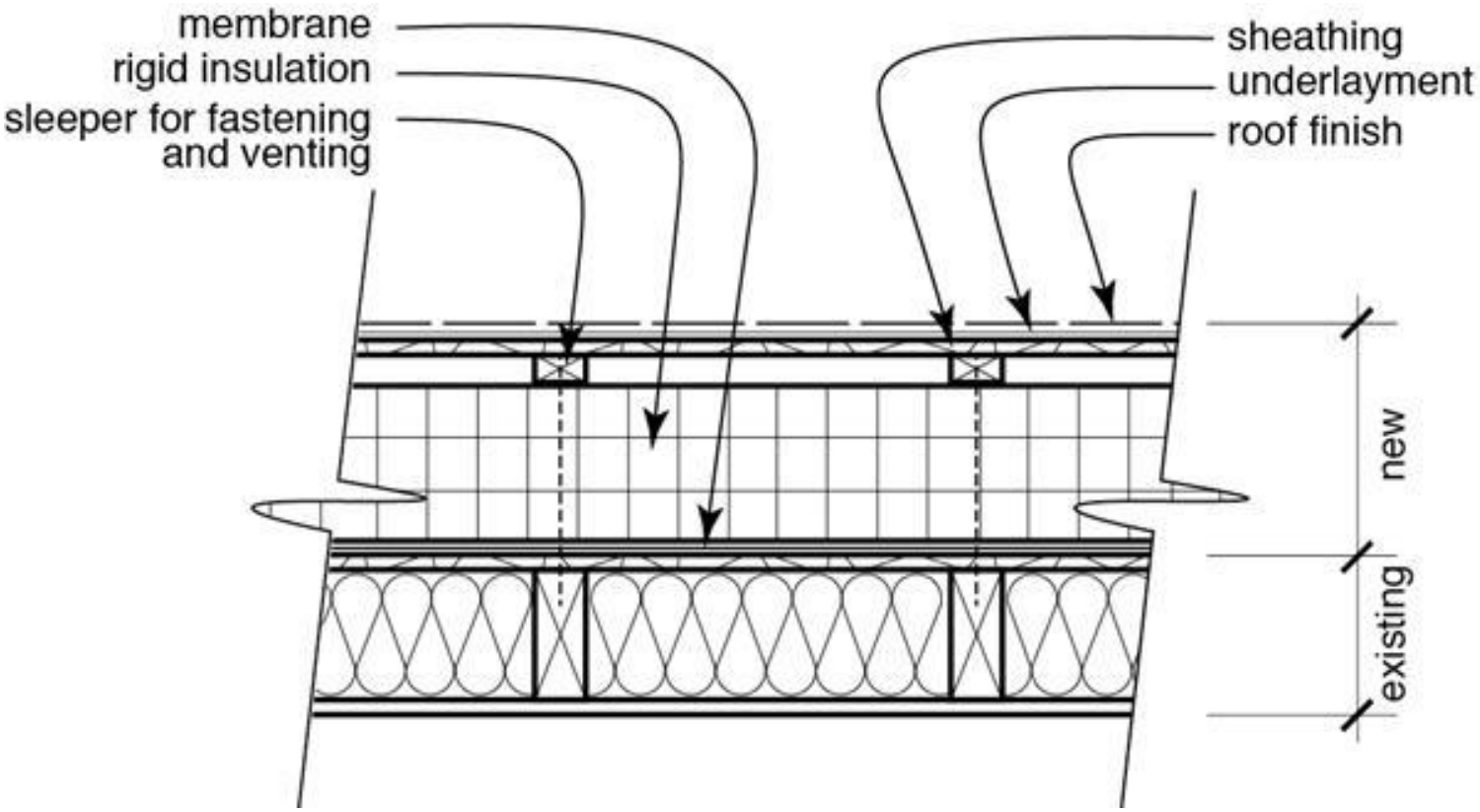
BEST OF NORTHERN*STAR*

- Work with a non-profit, affordable housing provider
  - Identify a classic 1-1/2 story house slated for renovation
- Demonstrate NorthernSTAR “capstone innovations”
  - “Excavationless” exterior foundation insulation
  - “Project Overcoat” for the roof
    - and walls, too (if appropriate and applicable)
  - Integrated space and water heating system
    - with source point ventilation
- Facilitate house tours and training opportunities
  - Before, during, and after the installations

ANATOMY OF AN ICE DAM



EXTERIOR INSULATION STRATEGIES



“PROJECT OVERCOAT”

- Remove existing roofing, overhang and trim
- Add “peel & stick” membrane
  - wrapped over bottom and sides
- Seal top plates and insulate gables
- Add 2 layers of polyiso rigid board foam
  - Staggered in both directions
- 2x4 furring with OSB, shingles & ridge vent
  - Build out overhang & finish trim