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We'll begin momentarily.
Moisture Management for Walls:
How to Do It Right the First Time & Why
Presented By: Patrick Huelman
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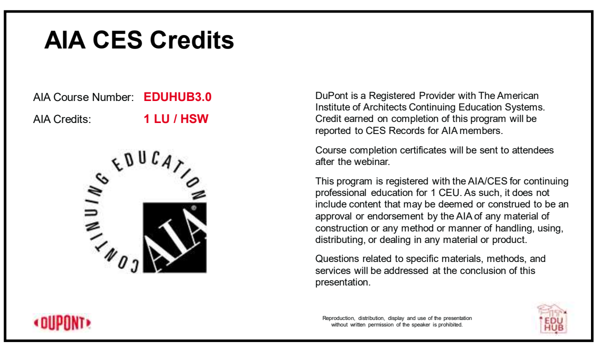
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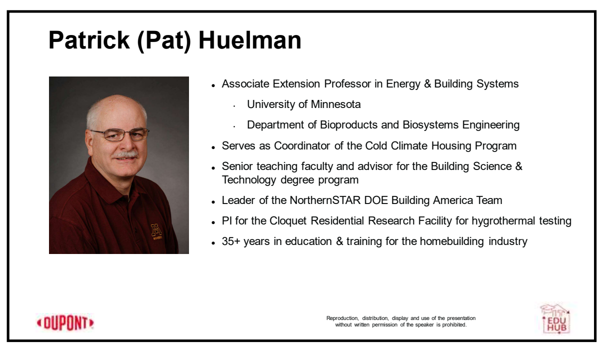
Patrick (Pat) Huelman
Associate Extension Professor in Energy & Building Systems
University of Minnesota
Department of Bioproducts and Biosystems Engineering
Serves as Coordinator of the Cold Climate Housing Program
Senior teaching faculty and advisor for the Building Science & Technology degree program
Leader of the NorthernSTAR DOE Building America Team
PI for the Cloquet Residential Research Facility for hygrothermal testing
35+ years in education & training for the homebuilding industry
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## MOISTURE MANAGEMENT FOR WALLS: HOW TO DO IT RIGHT THE FIRST TIME!

- Part 1: Why = Making a Case for Robust H-P Homes
- Part 2: What = It's All About the Control Layers
- Part 3: How = High-Performance Enclosure Systems

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



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## 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?



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## OVERARCHING THEMES

- We can and must do better!
  - 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.



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## THE FIVE THINGS*

- How did we get here
- What changed?
- How will we respond to these changes?
- What does this mean for building design and construction practices?

* Adapted from "BSI-039: The Five Things" by Joseph Lstiburek



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## FIVE FUNDAMENTAL CHANGES

- Increase thermal resistance
  - more insulation => less heat flow => less drying!
- Changes in permeability of linings
  - while this may mean less wetting,
  - it also can lead to very slow drying!
- Increased water/mold sensitivity of materials
- Moisture storage and redistribution
- Complex 3-D airflow networks in buildings

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## FIVE INEVITABLE TRENDS

- Building Airtightness
  - homes continue to get tighter everyday
- Mechanical Ventilation
  - moving towards balanced HRV/ERV systems & filtered air distribution
- Exterior Control Layers
  - especially continuous exterior insulation with vented cladding
- Ducts in Conditioned Space
  - this will drive the use of conditioned crawl spaces/attics
- Active Pressure Management
  - integrated make-up air & relief air

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## Building America Strategy

U.S. Department of Energy | Energy Efficiency & Renewable Energy

**Ultra-High Efficiency** + **High-Performance**

Ultra-High Efficiency:
- Enclosure
- Low-Load HVAC
- Components

High-Performance:
- Affordable
- Comfort
- Health
- Durability
- Renewable Readiness
- Water Conservation
- Disaster Resistance

12 | INNOVATION & INTEGRATION: Transforming the Energy Efficiency Market    Buildings.Energy.gov

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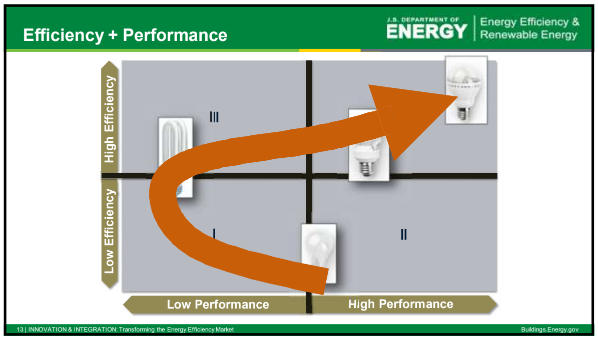


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## 1. MAKING THE CASE FOR ROBUST

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

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## 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.**

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## 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!**

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## 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



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## 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.



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## A QUICK BUILDING SCIENCE REVIEW

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



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## HEAT: FUNDAMENTALS

- Heat always flows from more energy (hot) to less energy (cold).
- There are three basic modes of heat transfer:
  – Conduction
  – Convection
  – Radiation



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## HEAT: THE BASICS OF HEAT LOSS/GAIN

- Heat moves through the building enclosure in two ways:
  - Transmission
    - through the opaque ceilings, walls, floors
    - through windows and doors
  - Air exchange (convective mass transport)
    - infiltration & exfiltration
    - exhaust devices
    - combustion equipment
    - ventilation

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## HEAT: THE BASICS OF HEAT LOSS/GAIN

- We must also recognize the role of:
  - Solar gains
    - windows, doors, skylights
  - Internal gains
    - lights, appliances, equipment
    - people and pets
- Both of these help offset winter heat losses, but can severely aggravate summer heat gains.

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## AIRFLOW: FUNDAMENTALS

- To have airflow you must have two things:
  - Pathway (or hole)
  - Pressure difference

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## AIRFLOW: THE BASICS

- Pathways
  - Unintentional – leaks and holes
  - Intentional – windows, ports, & ducts
- Pressures
  - Natural
    - wind
    - stack
  - Mechanical
    - combustion venting
    - exhaust & supply fans/devices
    - forced air systems

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## MOISTURE: FUNDAMENTALS

- Moisture States
  - Solid
  - Liquid => Absorbed
  - Vapor => Adsorbed



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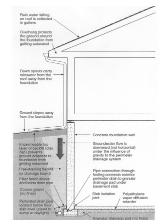
## MOISTURE TRANSPORT: LIQUID

- Gravity (Exterior Bulk Water)
  - Above Grade
    - roof leaks
    - window/door leaks
    - wall penetrations
    - saturated materials
  - Below Grade
    - surface drainage
    - saturated soils



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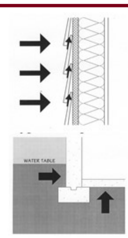
## MOISTURE TRANSPORT: LIQUID

- Pressure Driven Flow
  - Above grade
    - wind-driven rain
  - Below grade
    - rising water table





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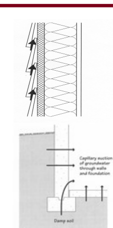
## MOISTURE TRANSPORT: LIQUID

- Capillary Action
  - Above grade
    - seams/joints
    - flashing
    - porous materials
  - Below grade
    - soils
    - footing/foundation
    - slab





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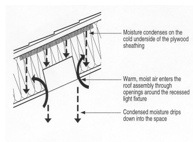
## MOISTURE TRANSPORT: VAPOR

- Air Flow
  - Above grade
    - interior/exterior moisture
    - air barrier integrity
    - indoor-outdoor pressures
  - Below Grade
    - soil moisture
    - air barrier integrity
    - basement-outdoor pressures

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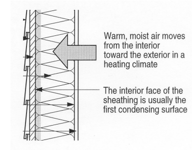
## MOISTURE TRANSPORT: VAPOR

- Diffusion
  - Above grade
    - vapor pressure gradient
      - outward in heating; inward in cooling
    - permeability
  - Below grade
    - vapor pressure gradient
      - upper wall is similar to above grade
      - lower wall and slab is primarily inward
    - permeability

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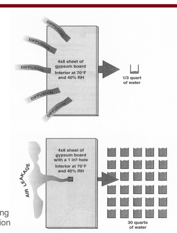
## MOISTURE TRANSPORT: VAPOR

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

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## 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!

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## 2. THE 4 CONTROL LAYERS

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



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## 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?



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## THERMAL CONTROL LAYER(S)

| Insulation Levels* | 0-1 2 3 4 4m 5 6 7-8 | NZE** |
|---|---|---|
| – Ceiling (flat) | \| 30 \|---- 49 ----\|-------------- 60 ---------------\| | 60 |
| – Walls | \|13/0+10\|20/13+5\|------- 20+5/13+10 -------\| | 40 |
| – Fenestration | \| NR \|--- 2.5 ----\|------------- 3.3 ----------------\| | 5 |
| – Floor (frame) | \|---- 13 ----\|---- 19 ----\|-------- 30 ---------\| 38 \| | 40 |
| – Foundation | \|----- 0 -----\|13/5\|13/10\|----- 19/13+5/15 -----\| | 20 |
| – Basement slab | \|-------------------------- 0 --------------------------\| | 10 |

* IECC 2021 - prescriptive R-values by Climate Zone
** From BSI-081 "Zeroing In" by Joseph Lstiburek



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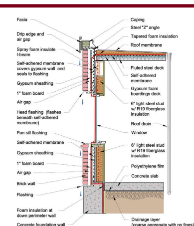
## PEN TEST: RED LINE FOR INSULATION



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## 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!

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## WATER CONTROL LAYER(S)

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

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## 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

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## WATER CONTROL LAYER(S)

- Drain, drain, drain!!!
  - use gravity to shed water down and out to manage rain, surface, and ground water
- 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

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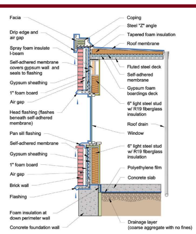
## PEN TEST: BLUE LINE FOR WATER

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## 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.

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## 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

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## AIR CONTROL LAYER(S)

- Airtightness* 0-1 2 3 4 5 6 7-8 NZE**
  - ACH @ 50Pa |--- 5.0 ---|--------------- 3.0 -----------------| 1.5

* IECC 2021 maximum building air leakage rates
** From BSI-081 "Zeroing In" by Joseph Lstiburek

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## 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!




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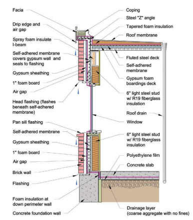
## PEN TEST: PURPLE LINE FOR AIR







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## 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




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## 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.




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## 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



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## 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
- However, the 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 protection



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## 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



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## 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.



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## 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?

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## 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 began to address air barriers.
- Then it became painfully apparent that we weren't paying sufficient attention to the management of bulk water.

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## THE MODERN ENCLOSURE CONUNDRUM

- However, only recently has the conversation turned to the importance of maintaining a drying potential
  - We recognize that 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 primarily by vapor diffusion
    - that can be outward in winter; inward in summer,
    - except below grade, which can only dry inward.

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## 3. HIGH-PERFORMANCE ENCLOSURES

- The "Perfect" Approach
  - Walls
  - Roof
  - Slab
  - Foundation
- Move the structure to the inside and the four control layers to the outside …
  - It simply works and works everywhere!!!

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## PERFECT H-P ENCLOSURES

- 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)

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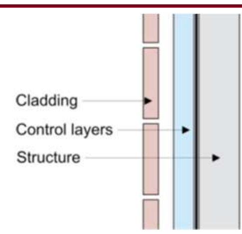
## THE PERFECT WALL (FROM BSC)




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

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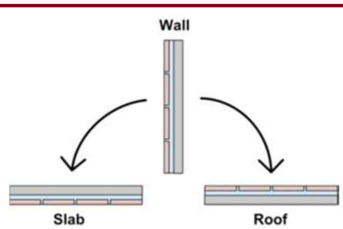
## WORKS FOR ROOF & SLAB, TOO!

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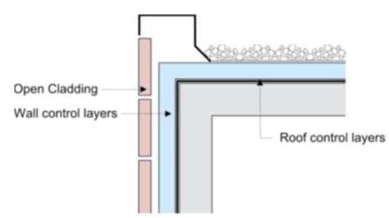
## PERFECT CONNECTIONS

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## 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!

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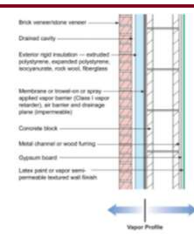
## THE PERFECT INSTITUTIONAL WALL




Courtesy of Building Science Corporation

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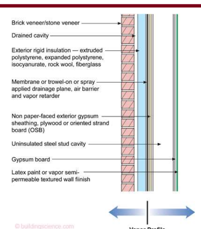
## THE PERFECT COMMERCIAL WALL

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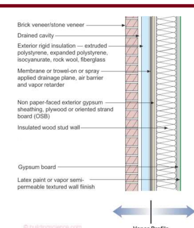
## THE PERFECT RESIDENTIAL WALL

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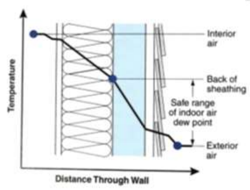
## HOW MUCH EXTERIOR INSULATION?

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




High Performance Enclosures: John Straube, 2012



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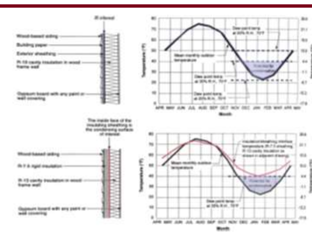
## CONDENSATION POTENTIAL



High Performance Enclosures: John Straube, 2012



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## % 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



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## IT'S TIME FOR A RECAP

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



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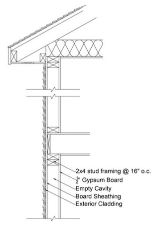
## Wall A: Older, Uninsulated Frame Wall




- 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 mean radiant temperature of interior surfaces
- ***It may be robust, but it is unacceptably inefficient and uncomfortable!***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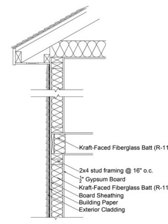
## Wall B: Older, Insulated Frame Wall




- Improved thermal efficiency
- Wetting potential goes up due to possible condensation; water intrusion remains high
- Drying potential is reduced as a result of less heat transfer and less permeable layers/linings
- Improved mean radiant temperature of surfaces, but may still be drafty
- ***More efficient, but not as durable or robust!***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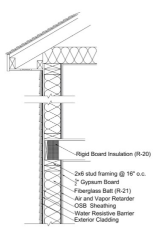
## Wall C: Typical Frame Wall




- 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!***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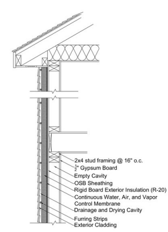
## Wall D: "Perfect Wall" w/ CEI




- Improved thermal and air control for higher energy efficiency
- All moisture transport mechanisms can be addressed for extremely low 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 robust, efficient, and comfortable!***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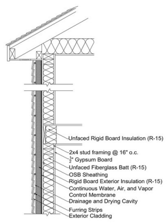
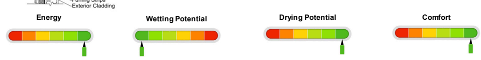
### Wall E: Hybrid Wall w/ CEI




- Outstanding energy performance
- All moisture transport mechanisms can be addressed for extremely low 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, and robust!***



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## 4. 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 good examples built upon the perfect wall and control layer methodology!**



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## 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 robust high-performance wall that is flexible for both site-built and panelization



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## EXTENDED PLATE WALL: SOLUTION


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



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## 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.



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## 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



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## 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.



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## 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




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## 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

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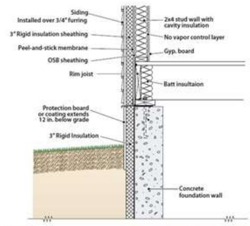
## WALL B: OPTI-MN (HYBRID) WALL

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**Team OptiMN**

**Won the Grand Prize**

In DOE's 2015 "Race to Zero"

Student Design Competition

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**INTRODUCING** | The Impact Home

INTRO | GOALS | DESIGN | ENCLOSURE | SYSTEMS | PERFORMANCE & FINANCIAL | CONCLUSION

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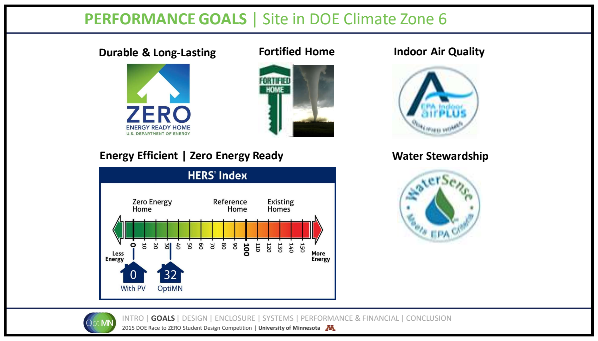
PERFORMANCE GOALS | Site in DOE Climate Zone 6
Durable & Long-Lasting
Fortified Home
Indoor Air Quality
ZERO
ENERGY READY HOME
U.S. DEPARTMENT OF ENERGY
FORTIFIED HOME
EPA Indoor airPLUS
Energy Efficient | Zero Energy Ready
Water Stewardship
HERS Index
Zero Energy Home
Reference Home
Existing Homes
Less Energy
More Energy
0
With PV
32
OptiMN
WaterSense
Meets EPA Criteria
INTRO | GOALS | DESIGN | ENCLOSURE | SYSTEMS | PERFORMANCE & FINANCIAL | CONCLUSION
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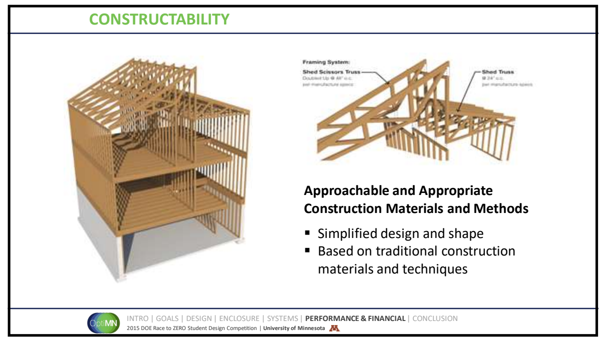
CONSTRUCTABILITY
Framing System:
Shed Scissors Truss
Shed Truss
Approachable and Appropriate Construction Materials and Methods
Simplified design and shape
Based on traditional construction materials and techniques
INTRO | GOALS | DESIGN | ENCLOSURE | SYSTEMS | PERFORMANCE & FINANCIAL | CONCLUSION
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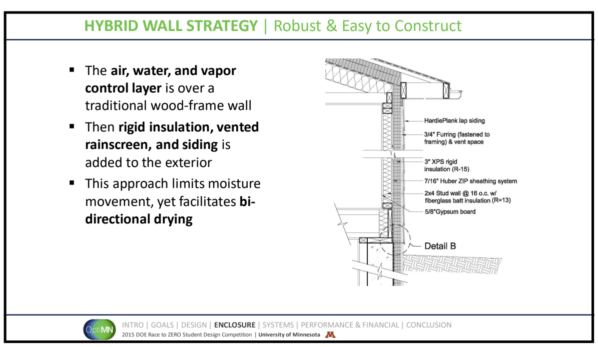
HYBRID WALL STRATEGY | Robust & Easy to Construct
The air, water, and vapor control layer is over a traditional wood-frame wall
Then rigid insulation, vented rainscreen, and siding is added to the exterior
This approach limits moisture movement, yet facilitates bi-directional drying
HardiePlank lap siding
3/4" Furring (fastened to framing) & vent space
3" XPS rigid insulation (R-15)
7/16" Huber ZIP sheathing system
2x4 Stud wall @ 16 o.c. w/ fiberglass batt insulation (R=13)
5/8"Gypsum board
Detail B
INTRO | GOALS | DESIGN | ENCLOSURE | SYSTEMS | PERFORMANCE & FINANCIAL | CONCLUSION
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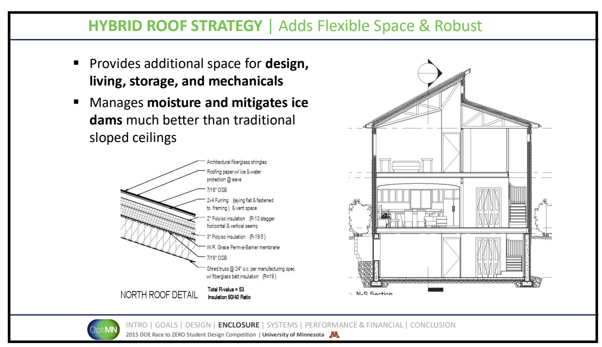
HYBRID ROOF STRATEGY | Adds Flexible Space & Robust
Provides additional space for design, living, storage, and mechanicals
Manages moisture and mitigates ice dams much better than traditional sloped ceilings
Architectural fiberglass shingles
Roofing paper w/ ice & water protection @ eave
7/16" OSB
2x4 Furring (laying flat & fastened to framing) & vent space
2" Polyiso insulation (R-13 stagger horizontal & vertical seems
3" Polyiso insulation (R-19.5)
W.R. Grace Perm-a-Barrier membrane
7/16" OSB
Shred truss @ 24" o.c. per manufacturing spec w/ fiberglass batt insulation (R=19)
NORTH ROOF DETAIL
Total R-value = 53
Insulation 60/40 Ratio
INTRO | GOALS | DESIGN | ENCLOSURE | SYSTEMS | PERFORMANCE & FINANCIAL | CONCLUSION
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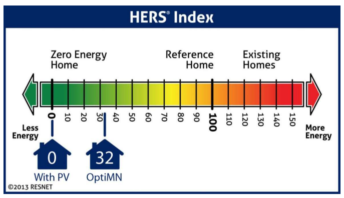
PERFORMANCE




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

INTRO | GOALS | DESIGN | ENCLOSURE | SYSTEMS | **PERFORMANCE & FINANCIAL** | CONCLUSION
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## OPTI-MN (HYBRID): CONTROL LAYERS

- Water Control
  - "Peel & stick" membrane on sheathing
  - Drainage behind cladding
- 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

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## 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

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## 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

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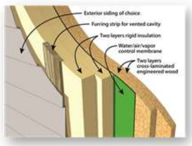
## SPS SYSTEM: MARKET DRIVERS

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

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## SPS SYSTEM: "PERFECT WALL" FUNDAMENTALS

- 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

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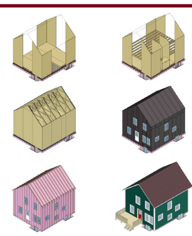
## SPS: BENEFIT OF SINGLE ENCLOSURE CONTRACTOR

- 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



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Dryer
Elec Service
Hose Bib

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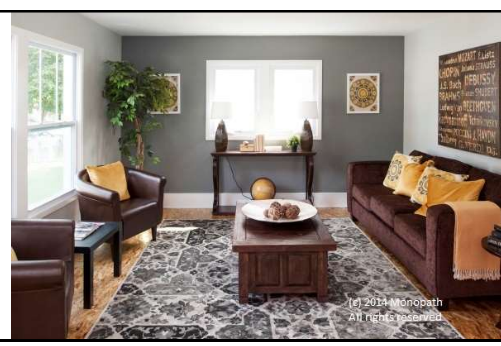
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## SPS SYSTEM: CONTROL LAYERS

- 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

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## 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!

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## 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

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## 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

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## 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

**=> Your one stop shop => BASC.energy.gov**

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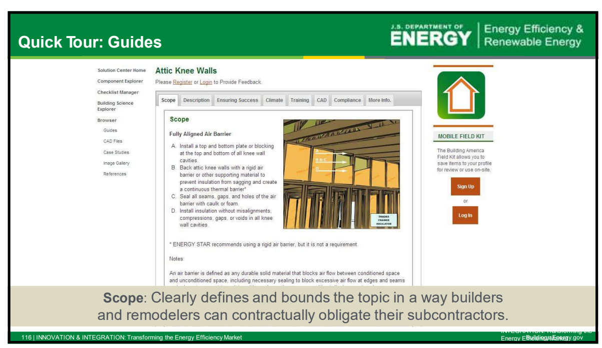


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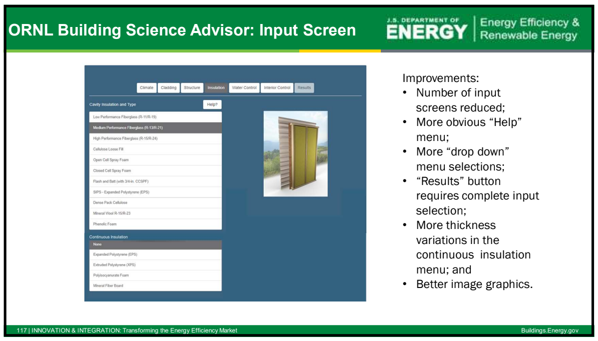


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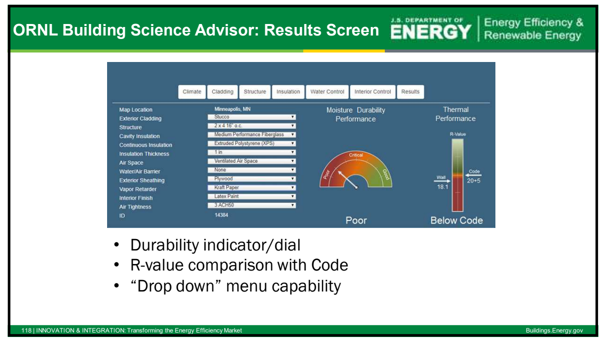


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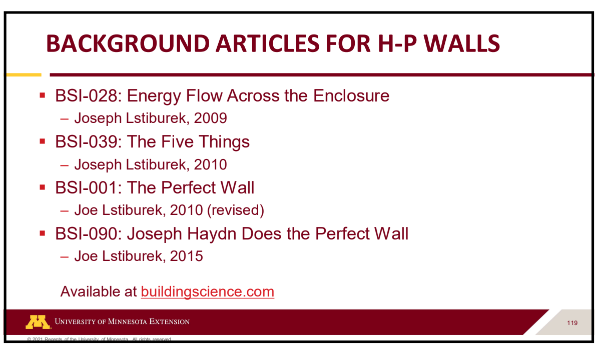


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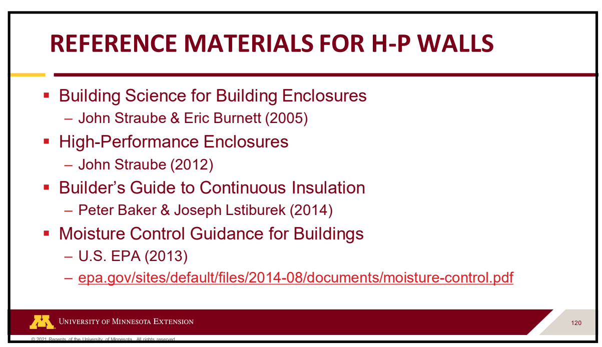


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## BUILDING AMERICA RESOURCES FOR H-P WALLS

- 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

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Driven to Discover

## Contact Information

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



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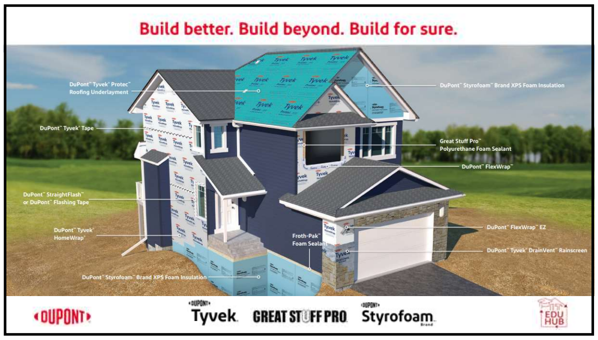


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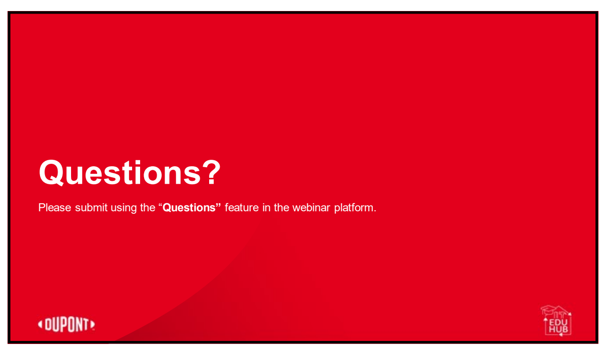


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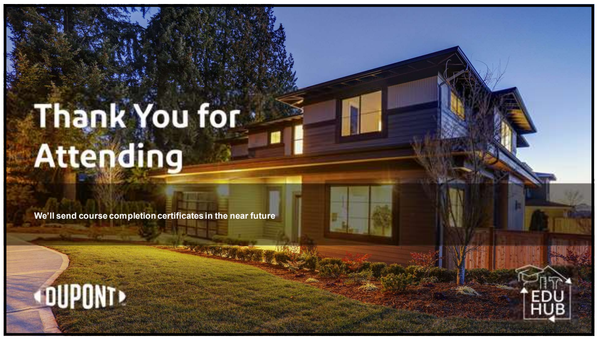
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