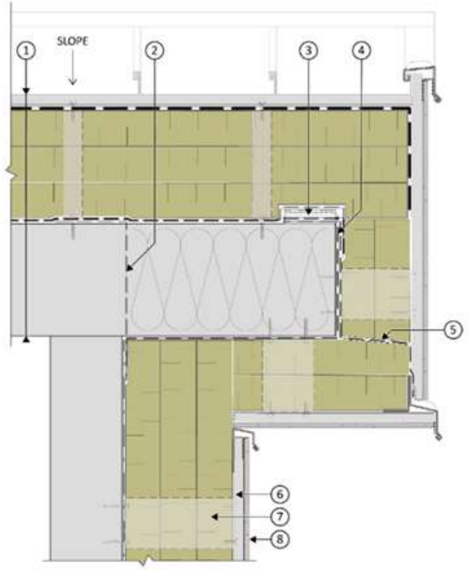

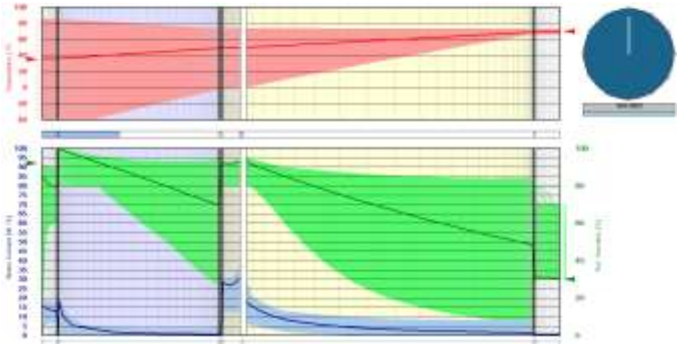

Lyle Axelarris, PE, LEED AP

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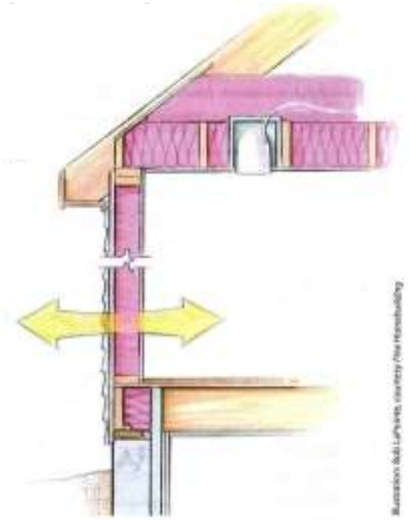
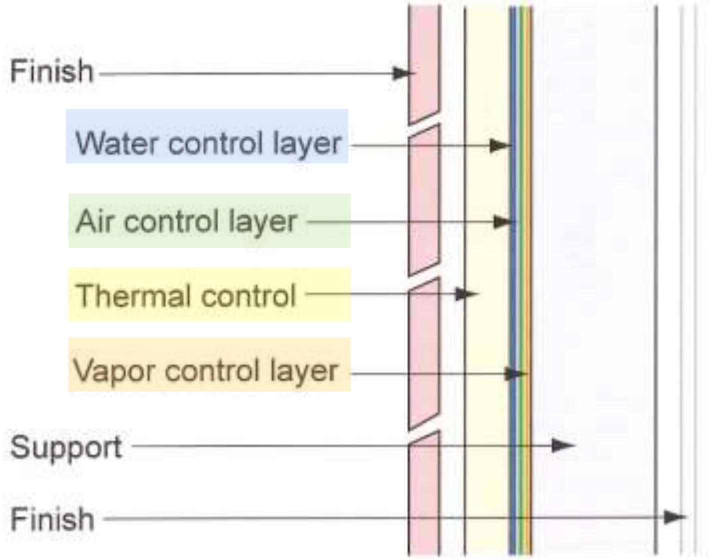
Building Envelope Design for Thermal Resiliency

Foundation, Wall, and Roof assemblies are SYSTEMS of materials that must work together to provide a continuous barrier of thermal, air, and water control layers that separate the outside climate from the inside climate.





The fourth control layer is vapor diffusion, but it does not necessarily need to be a "barrier".

Providing drying potential (low vapor diffusion resistance) is much more important than attempting to prevent vapor diffusion.

Image Credit: John Straube, Building Science Press
Image Credit: Fine Home Building


Recommended Insulation Levels
Thermal Barrier Continuity
Thermal Barrier
Finish
Water control layer
Air control layer
Thermal control
Vapor control layer
Support
Finish


Wetting / Storage / Drying
Type & Location of Insulation matters
Hygrothermal modeling – ASHRAE 160
Vapor Profile
Finish
Water control layer
Air control layer
Thermal control
Vapor control layer
Support
Finish


Putting It All Together
Finish
Water control layer
Air control layer
Thermal control
Vapor control layer
Support
Finish

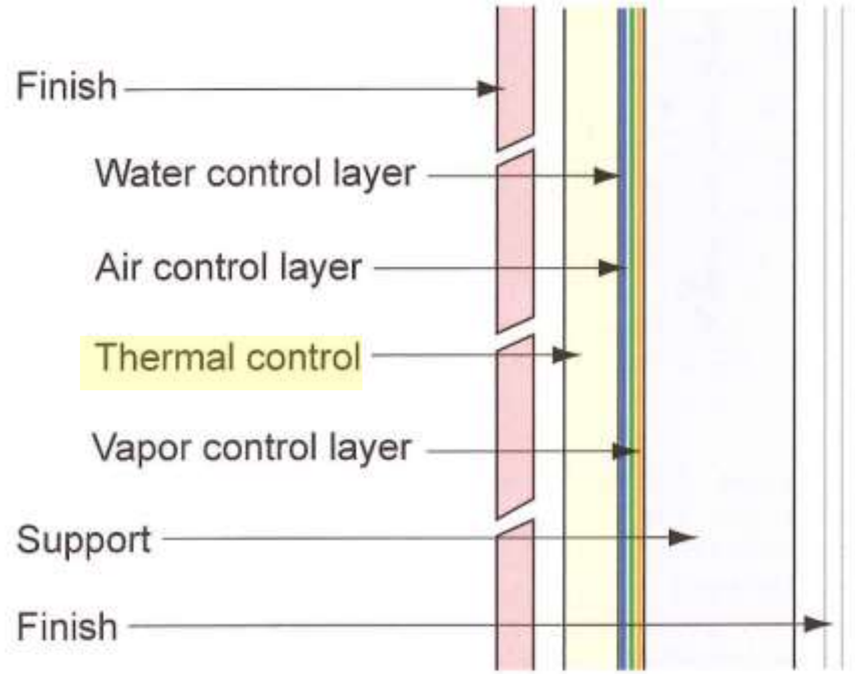

Energy / Heat loss impacts
Recommended Airtightness Levels
Air Barrier Continuity – localized damage
Air Barrier
Finish
Water control layer
Air control layer
Thermal control
Vapor control layer
Support
Finish


Energy / Heat loss impacts
IAQ / Durability impacts
Water Barrier
Finish
Water control layer
Air control layer
Thermal control
Vapor control layer
Support
Finish

Recommended Insulation Levels

Thermal Barrier Continuity

Thermal Barrier



High-Performance Thermal Standards

- varies by climate, construction typology, economic and societal parameters.
- Does not address thermal resiliency
- Higher standards Prolong habitability of building during outage

Country/Climate Zone	Standard	Walls Minimum Insulation Value	Roof Minimum Insulation Value
	Units	°F·ft²·hr/Btu	°F·ft²·hr/Btu
Canada	Nunavut Good Building Practices	R-28	R-40
	Northwest Territories Good Building Practices	R-32	R-50
	Yellowknife - Existing Buildings	R-30	R-40
	Yukon Housing Corporation	R-28 Whitehorse R-21 Elsewhere	R-59
	General Passive House Guidelines	R-60 TO R-80+	R-60 TO R-100+
	National Energy Code of Canada for Buildings 2017 – Climate Zone 7	R-27	R-41

Country/Climate Zone	Standard	Walls Minimum Insulation Value	Roof Minimum Insulation Value
	Units	°F·ft²·hr/Btu	°F·ft²·hr/Btu
Alaska	Deep Energy Retrofit Climate Zone 7	R-50	R-65
	Deep Energy Retrofit Climate Zone 8	R-50	R-75
	Alaska Building Energy Efficiency Standard Climate Zone 7	R-25	R-54 or 48*
	Alaska Building Energy Efficiency Standard Climate Zone 8	R-30	R-59 or 48*
	MILCON Initial Compliant Standards	R-45	R-60

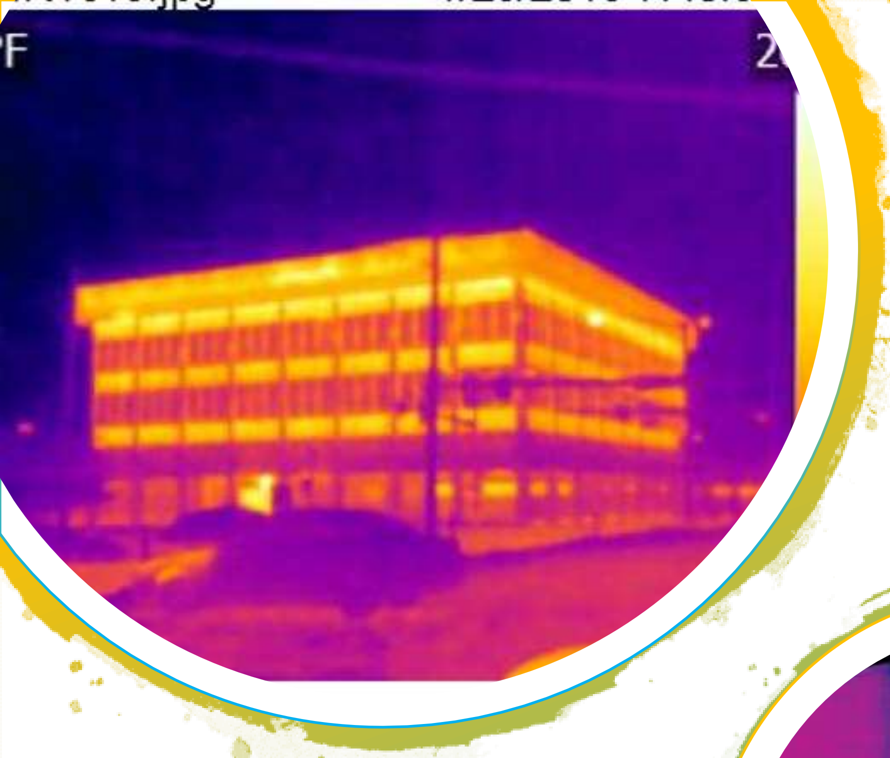
* The smaller value may be used with a properly sized, energy-heel truss.

Country/Climate Zone	Standard	Walls Minimum Insulation Value	Roof Minimum Insulation Value
	Units	°F·ft²·hr/Btu	°F·ft²·hr/Btu
China	Deep Energy Retrofit Climate Zone 7	R-19	R-19
Finland	Decree of the Ministry of the Environment on the Energy Performance of New Building	R-35	R-65
Norway	Norwegian Regulations	R-26	R-32
Greenland	Greenlandic Building Regulations	R-28 for weight<100 kg/m² or R-19 for weight>100 kg/m²	R-38 (R-28 flat roofs)

High-Performance Thermal Envelope

- In U.S., current high-performance standards for most federal new construction projects requires a 30% energy reduction compared to the ASHRAE 90.1-2013 baseline building.
- The most effective strategy to reach this goal is to focus on reducing HVAC loads with a high-performance building envelope.
- This will reduce energy costs, improve thermal comfort, and prolong the habitability of the building during disruptions to heat supply.

	R-Value for 30% improvement over ASHRAE 90.1-2013 (°F·ft²·hr/Btu)											
	Roof			Above-Grade Walls				Slab on Grade		Fenestration		
ASHRAE Climate Zone	Insulation Entirely above Deck	Metal Building	Attic	Mass Wall	Metal Building	Steel Framed	Wood Framed & Other	Unheated (Vertical Insulation for 48")	Heated (Vertical Insulation for 48")	Entrance Doors	Metal Windows (Fixed/ Operable)	Nonmetal Windows
Zone 8 (Fairbanks)	46.4	50	76.5	27.1	33.3	35.1	40.6	26	32.5	1.7	3.4 / 3.3	4.1
Zone 7 (Anchorage)	46.4	44.8	76.5	18.3	29.5	26.5	25.5	9.8	32.5	1.7	3.4 / 3.3	4.1
Zone 6 (Minneapolis)	40.6	41.9	61.9	16.3	26.0	26.5	25.5	9.8	26	1.7	3.1 / 2.6	4.1



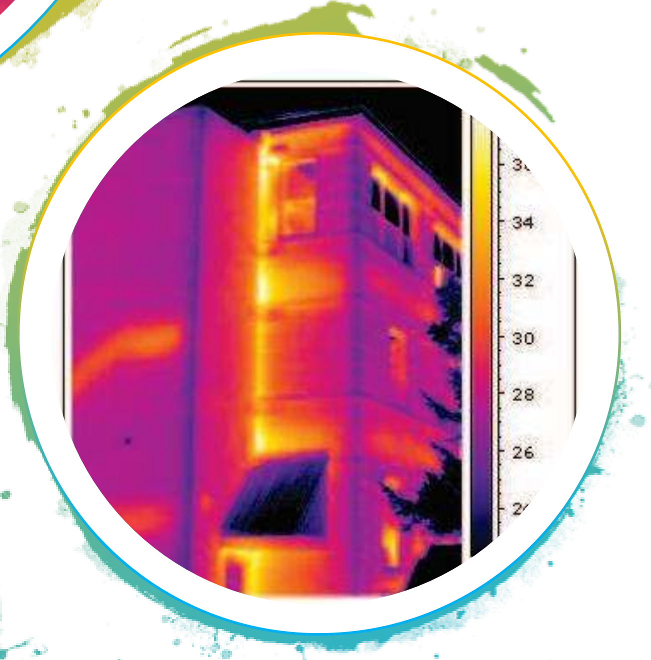
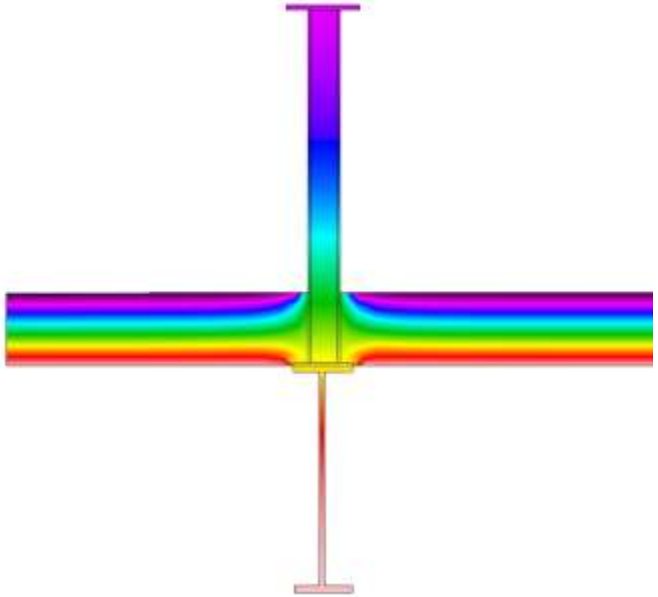


Image Credit: Design Alaska

Thermal Bridging

- Energy Loss
- Condensation

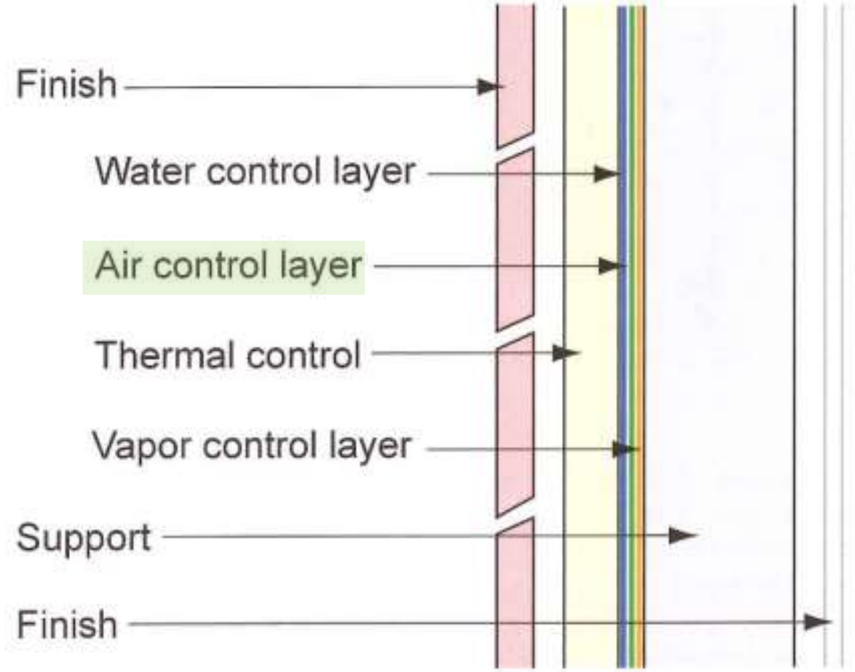


Air Barrier

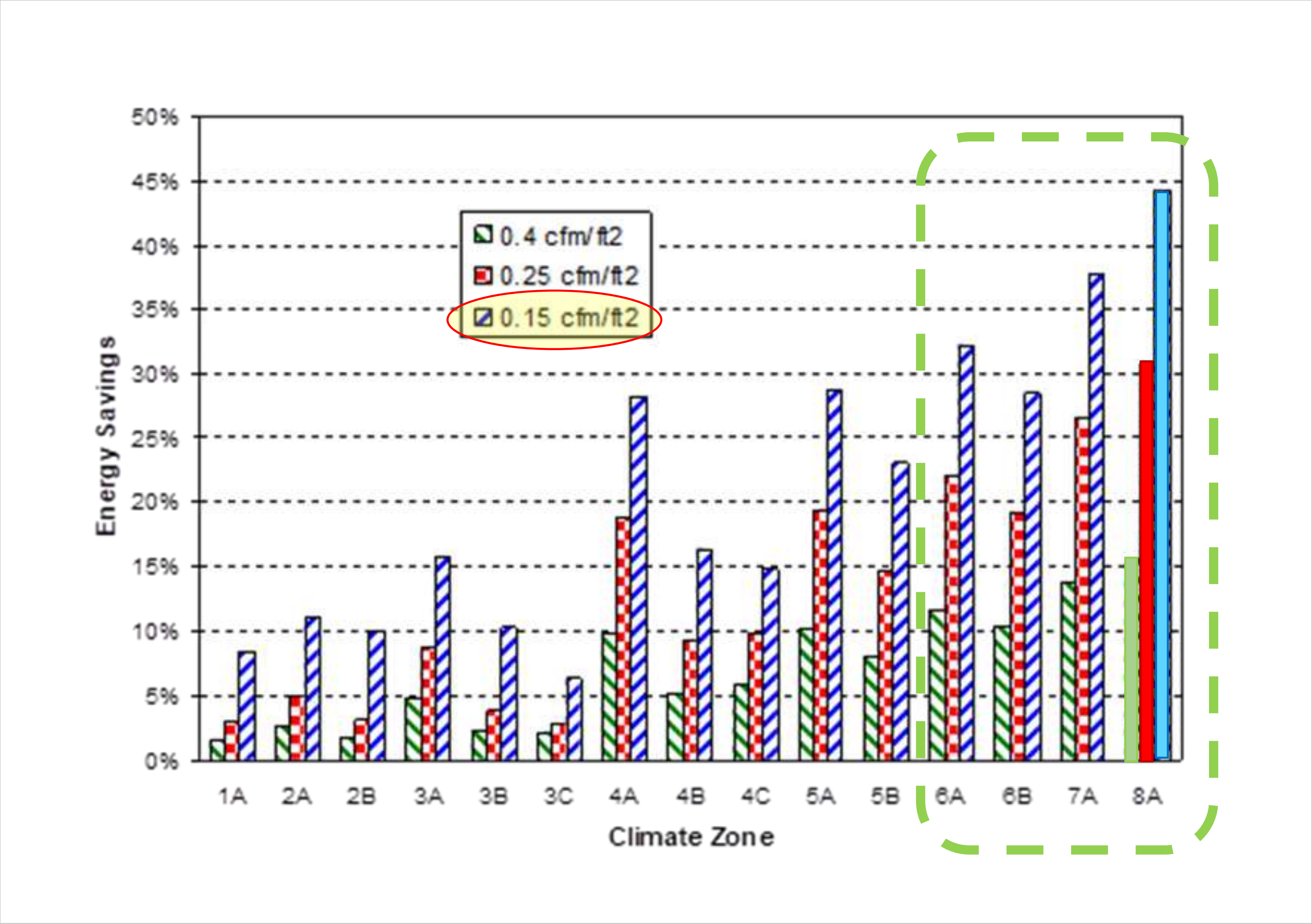
Energy / Heat loss impacts

Recommended Airtightness Levels

Air Barrier Continuity – localized damage



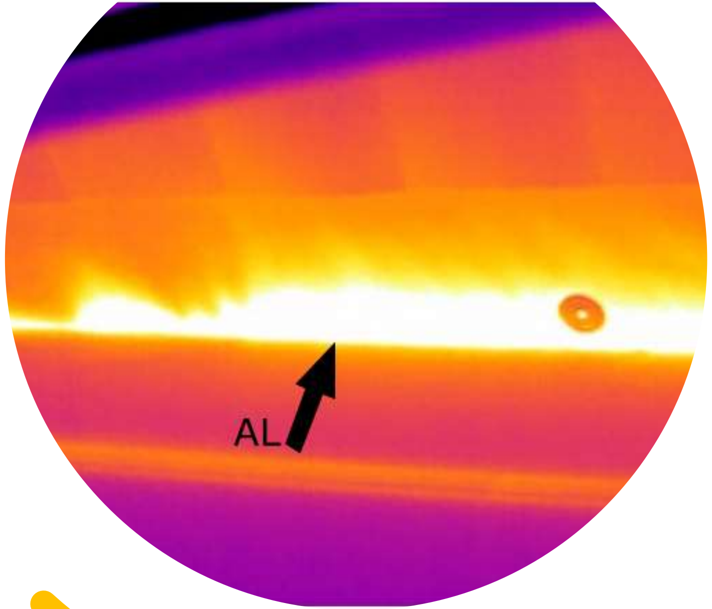
Energy Savings

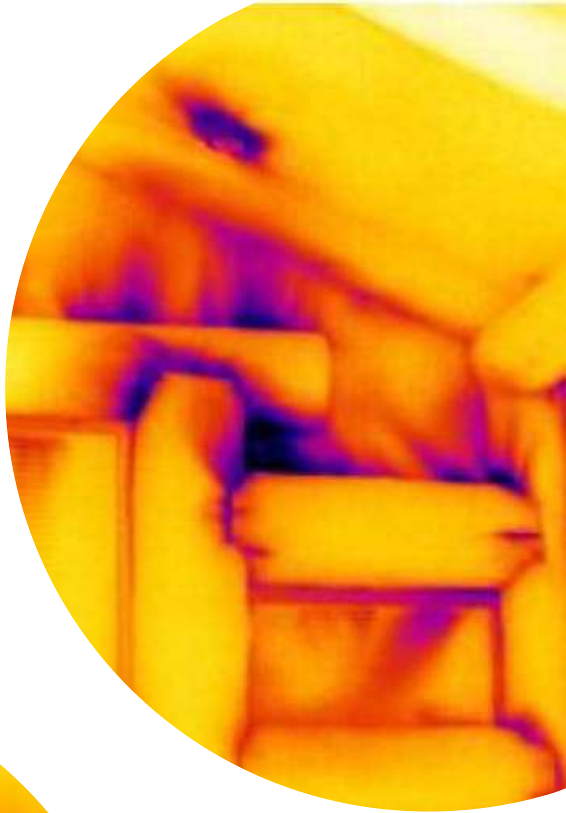


Source: A. Zhivov, Herron, D., Durston, J.L., Heron, M., and G. Lea. 2014. “Airtightness in New and Retrofitted U.S. Army Buildings.” International Journal of Ventilation. 12(4):317-330

Air Leakage

- Energy Loss
- Condensation





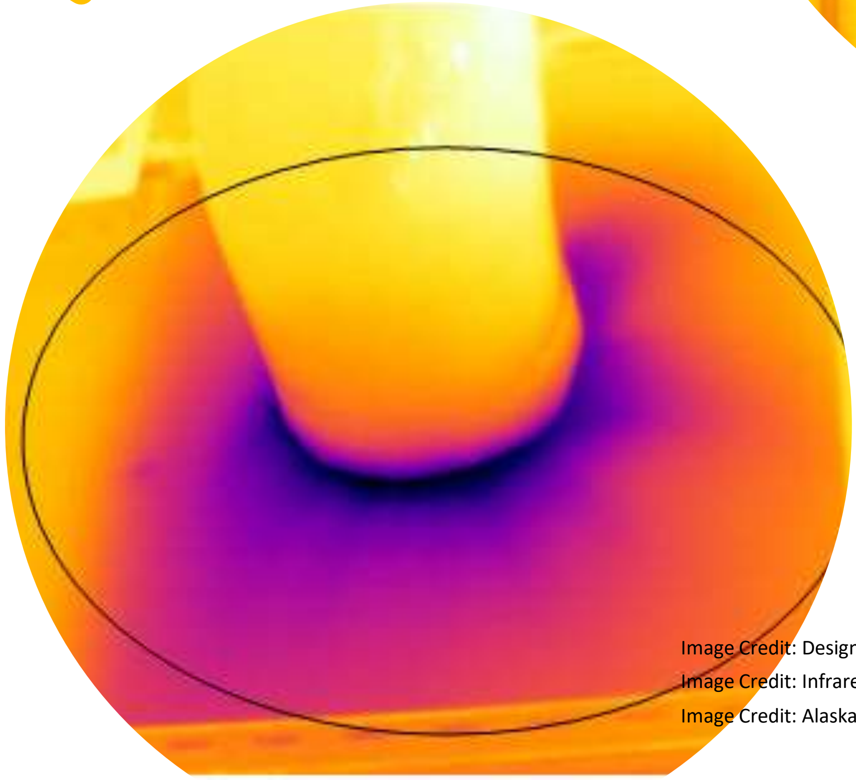
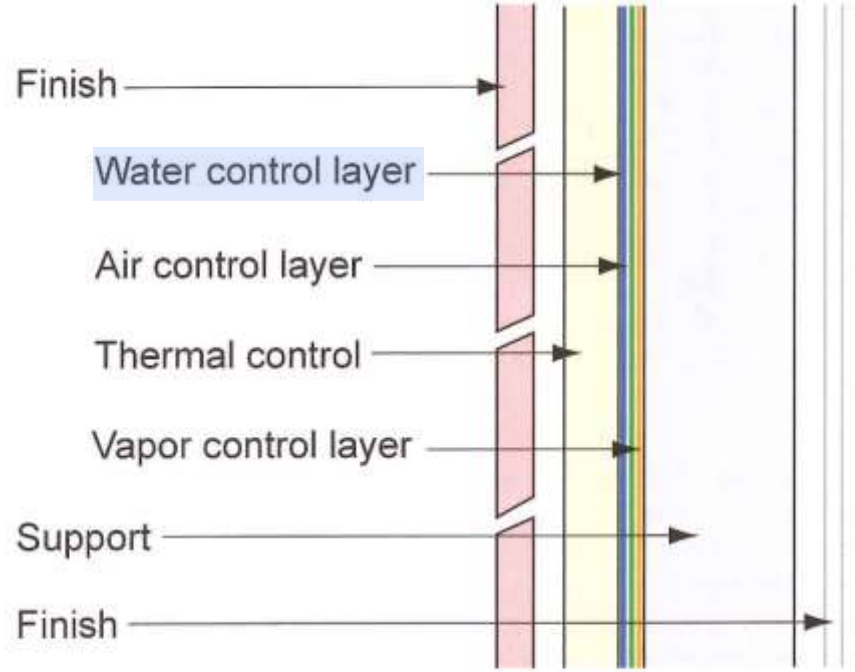


Image Credit: Design Alaska
Image Credit: Infrared Training Center
Image Credit: Alaska Thermal Imaging

Energy / Heat loss impacts

IAQ / Durability impacts

Water Barrier



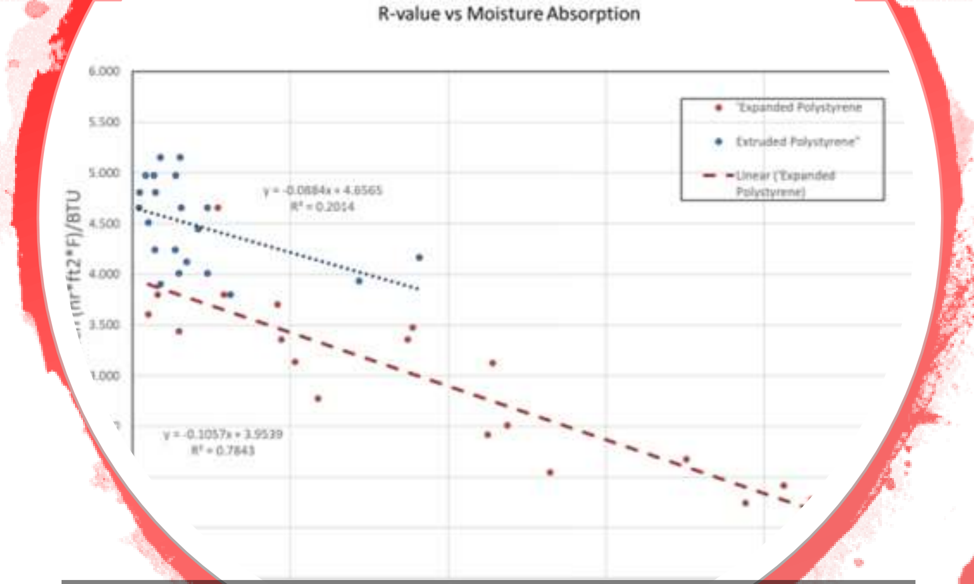
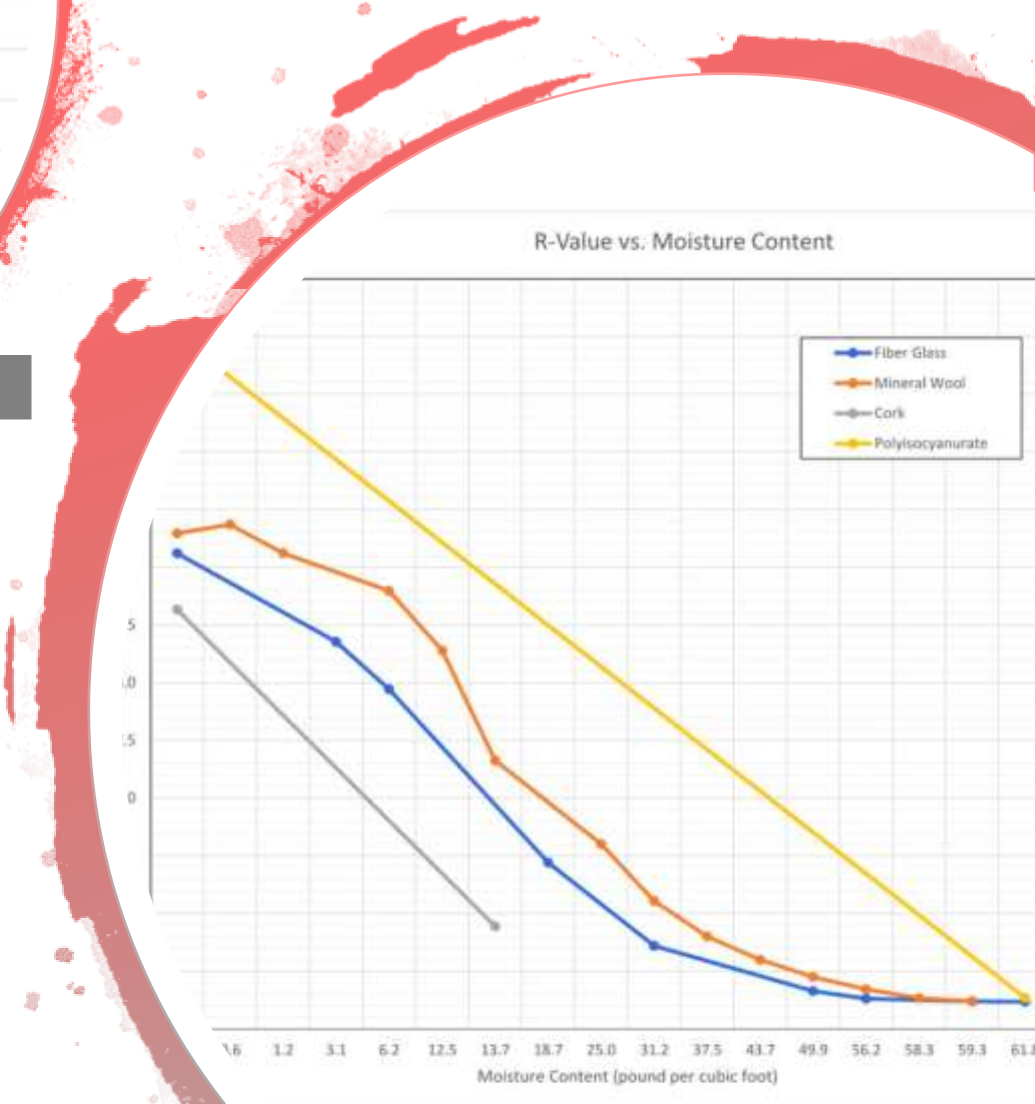


Image Credit: Connor, AUTC / UAF 2019



Data Source: WUFI material database, Fraunhofer Institute for Building Physics

R-value is dependent on moisture content

Water Barrier Failure impacts Thermal Barrier

No kickout flashing causes staining…

… rot, and poor thermal performance

Air and Thermal Barrier Failure impacts Water Barrier

Hot Roof in Winter…

… causes leaks in Summer

Image Credit: Design Alaska

80% of construction defect litigation is due to moisture-related failures [1]

>$7 Billion annually to correct moisture-related construction defects [1]

$3.5 Billion spent annually on asthma-related medical costs attributable to exposures to dampness and mold (Berkeley Lab estimate) [2]

Image Credit: American Phytopathological Society

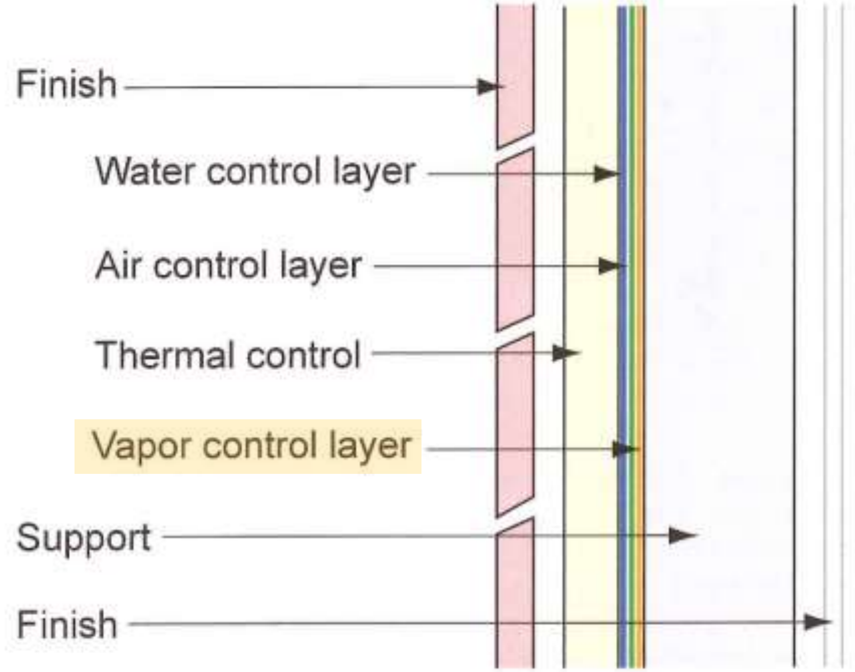
1. Source: Fitzgerald, J. (2007). "Preventing moisture-related problems in residential wood framing." Continuing Education Center <http://continuingeducation.construction.com/article.php?L=94&C=265> (Dec. 5, 2007).
2. Source: D. Mudarri, W. J. Fisk (2007) Public health and economic impact of dampness and mold. Indoor Air 17 (3), 226–235. doi:10.1111 /j.1600-0668.2007.00474.x

Wetting / Storage / Drying

Type & Location of Insulation matters

Hygrothermal modeling – ASHRAE 160

Vapor Profile



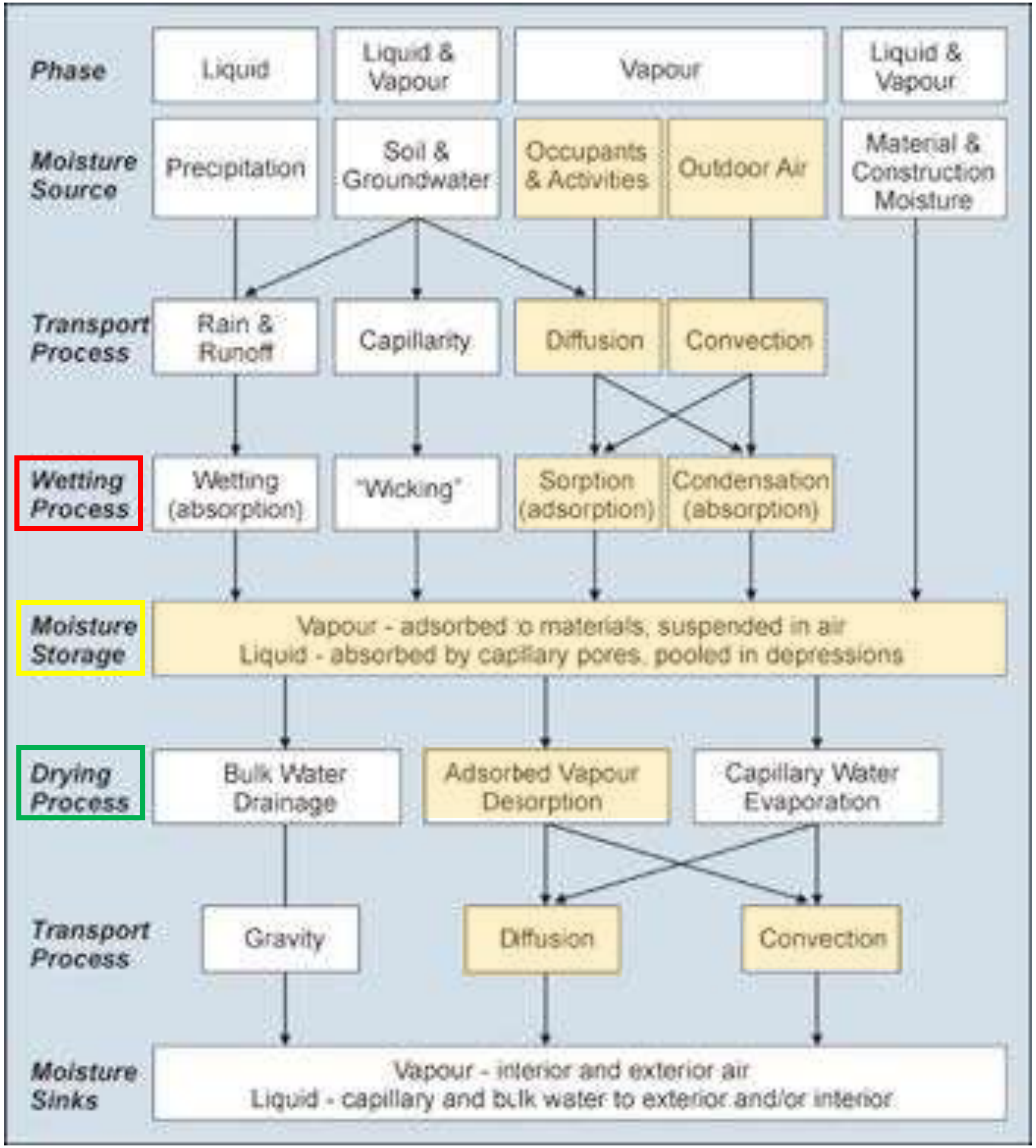
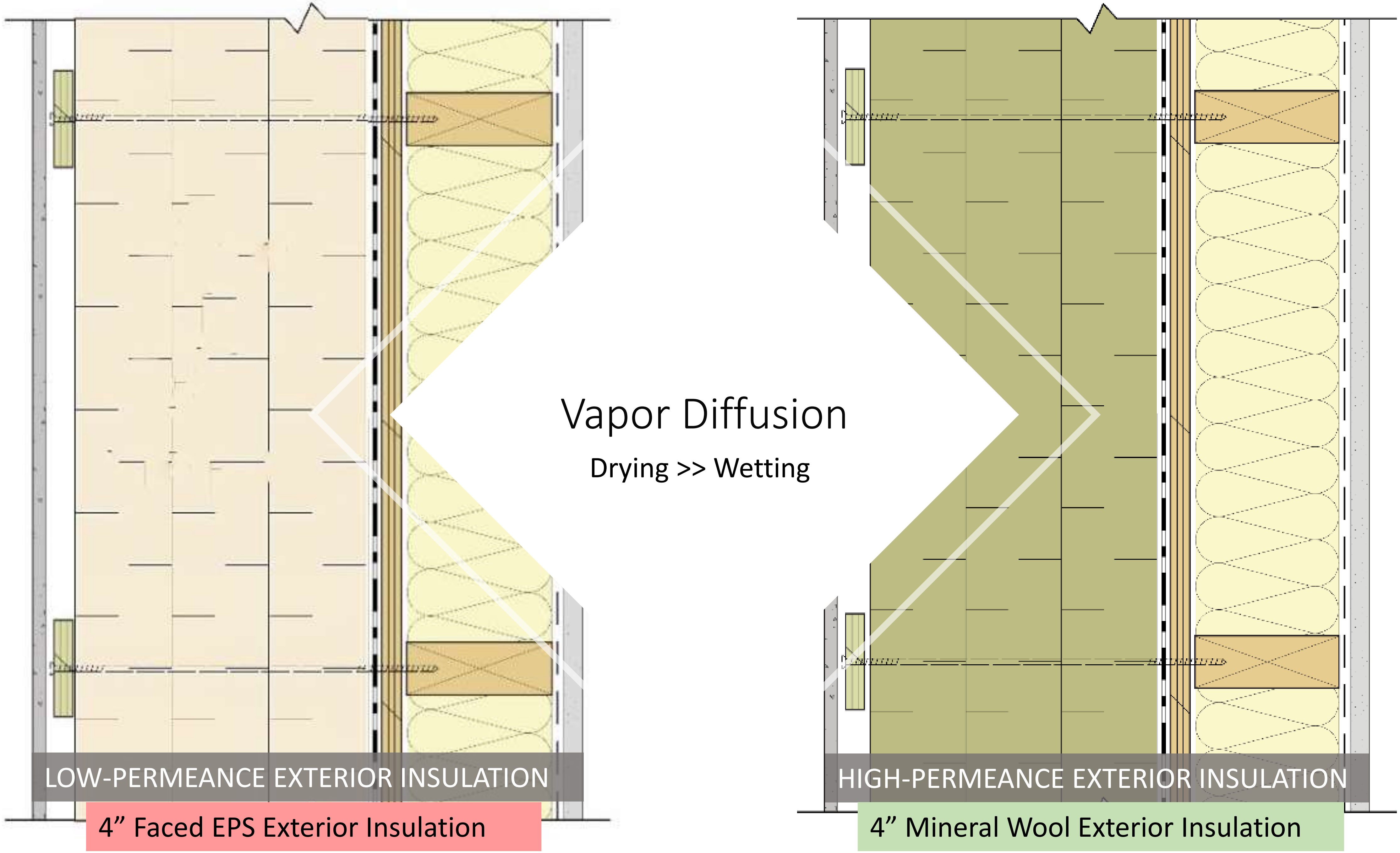


Image Credit: John Straube, ASHRAE Journal

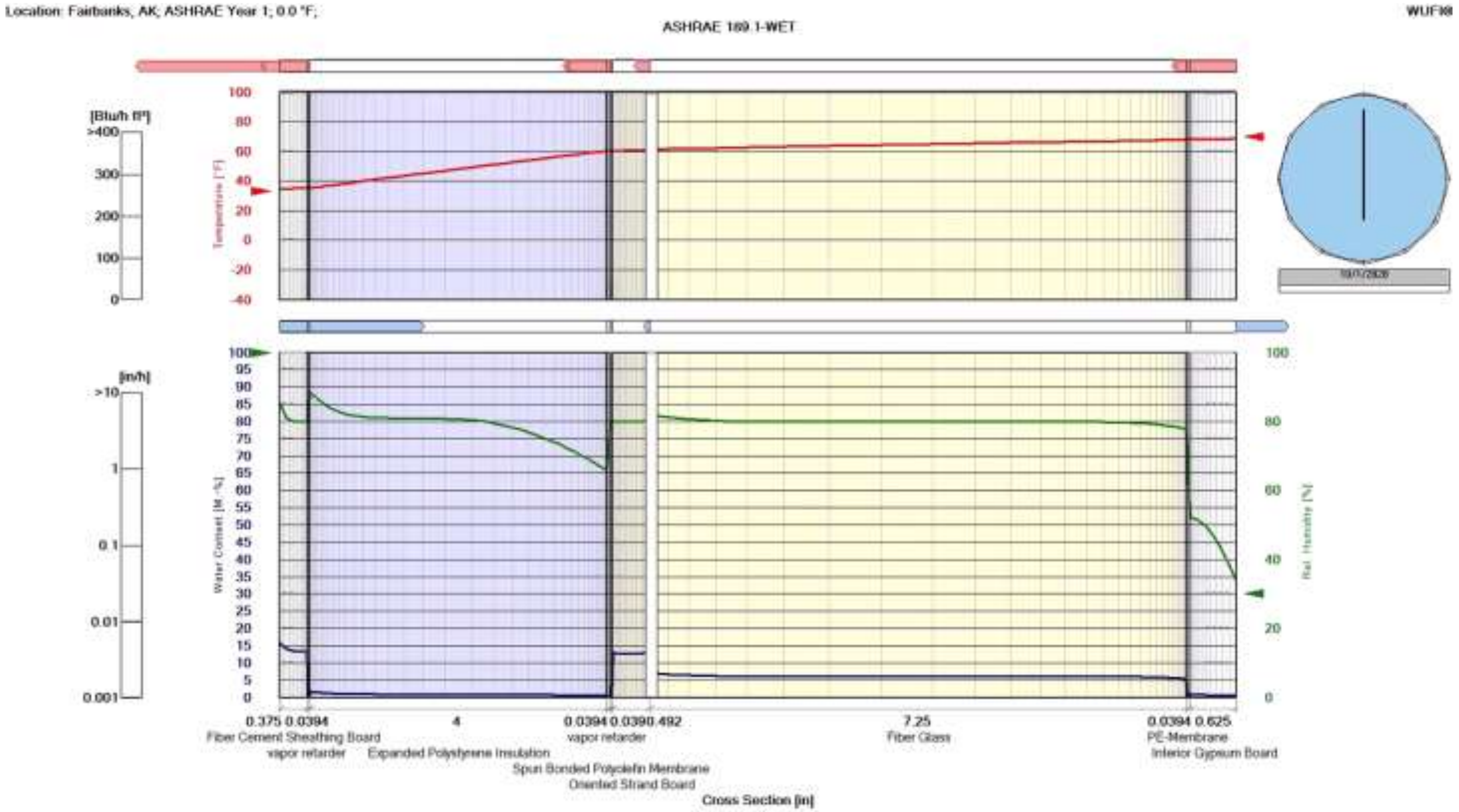


Vapor Diffusion
Drying >> Wetting
LOW-PERMEANCE EXTERIOR INSULATION
4” Faced EPS Exterior Insulation
HIGH-PERMEANCE EXTERIOR INSULATION
4” Mineral Wool Exterior Insulation

Hygrothermal Modeling – Split Insulated Wood Wall with Interior Vapor Barrier and **Low Perm** Exterior Insulation

- Large Amounts of Moisture (Blue) accumulate in the OSB during Winter
- Low-Perm materials on both sides of OSB retard the drying process during Summer
- Classic "Double Vapor Barrier" problem

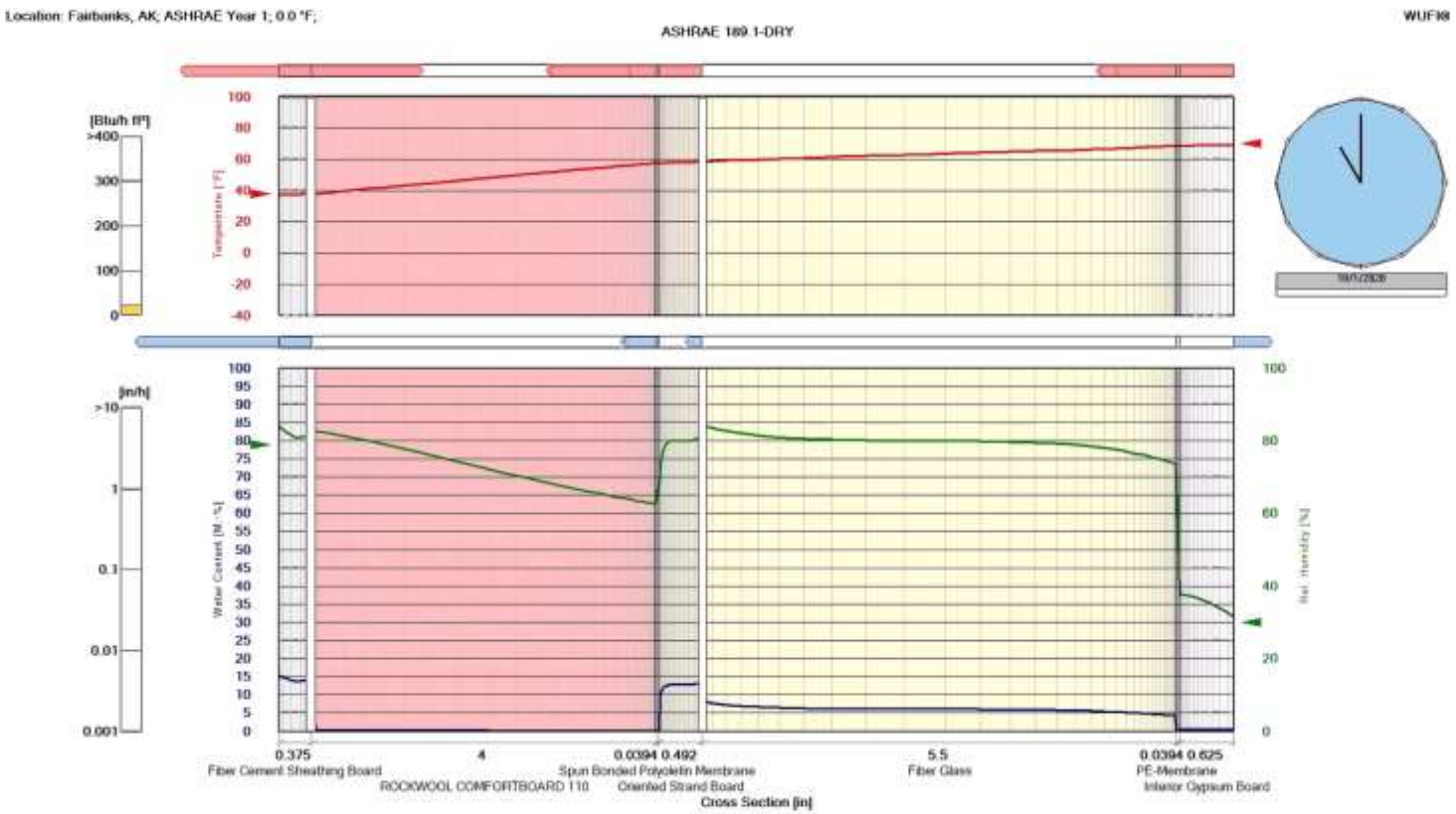
4" Faced EPS Exterior Insulation



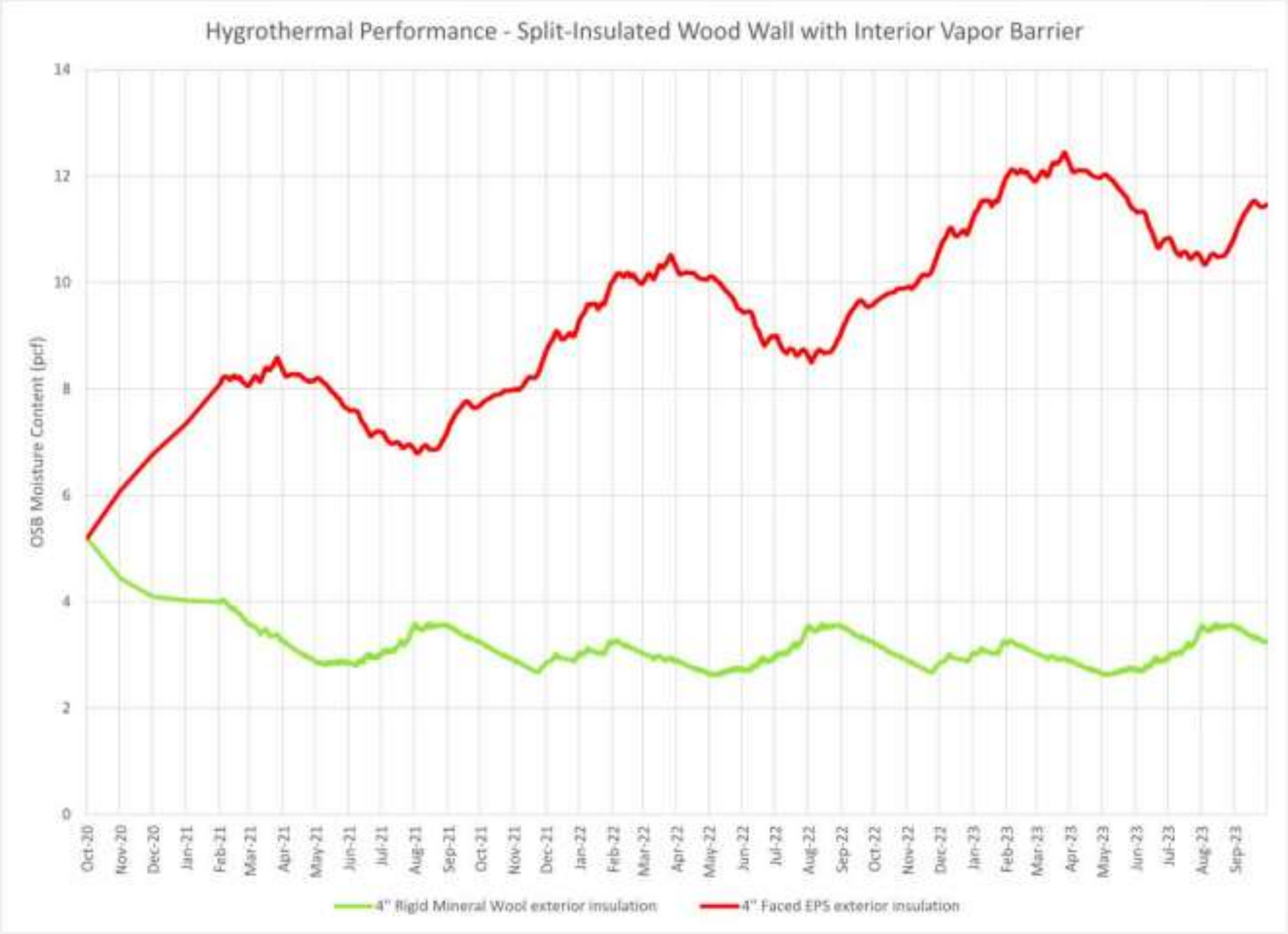
Hygrothermal Modeling – Split Insulated Wood Wall with Interior Vapor Barrier and **High Perm** Exterior Insulation

- Some Moisture (Blue) accumulates in the OSB during Winter
- High-Perm Mineral Wool exterior insulation expedites the drying process during Summer
- “Dry to the Exterior” – works great in cold, dry climates (Fairbanks)

4” Mineral Wool Exterior Insulation



Hygrothermal Modeling – Split Insulated Wood Walls with Interior Vapor Barrier

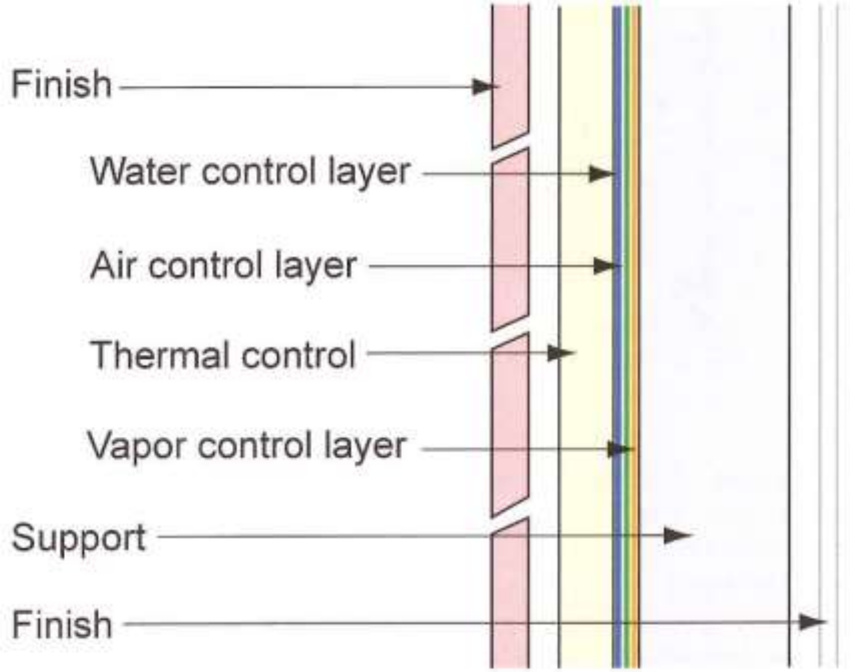


High Performance

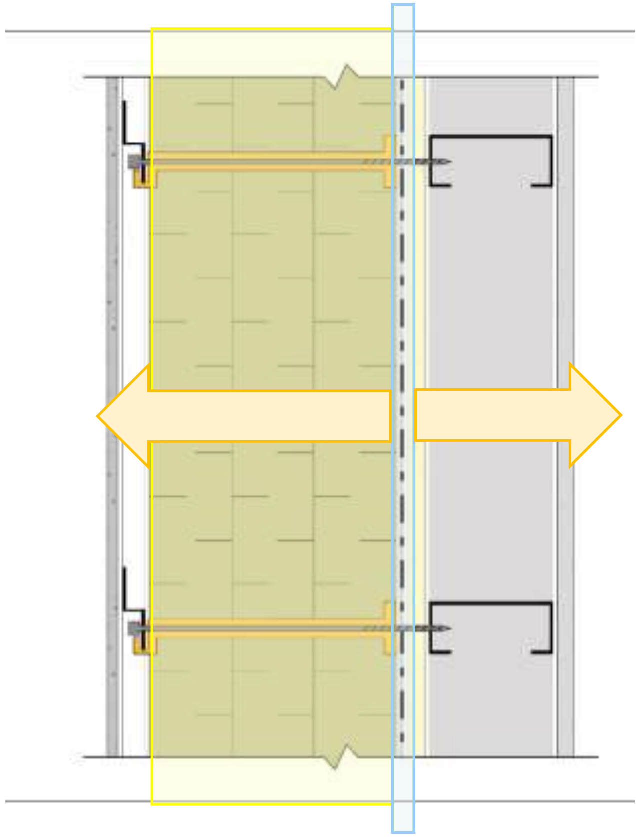
Barrier Continuity

Balanced Vapor Profile

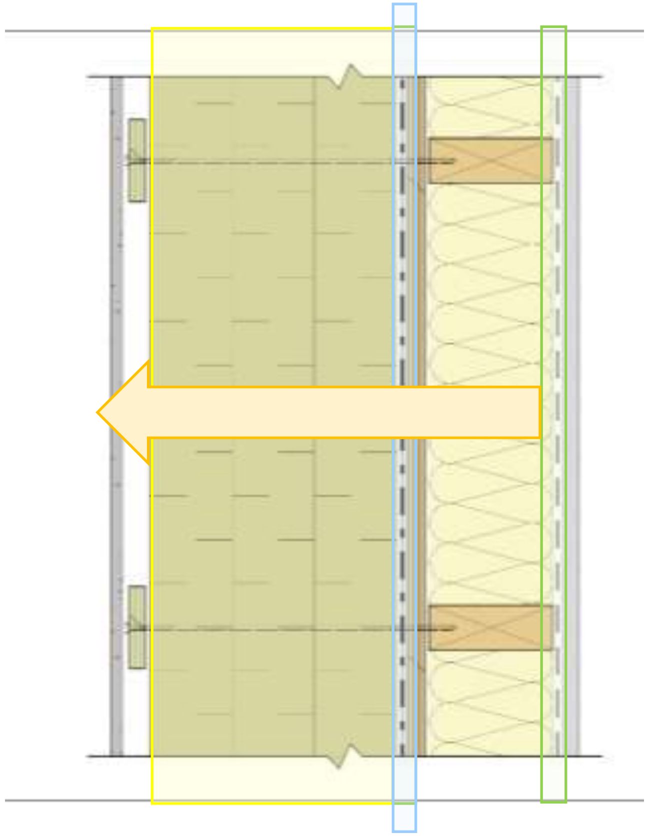
Putting It All Together



Wall Assembly



EXTERIOR INSULATED WALL



SPLIT-INSULATED WALL

Thermal Barrier Continuity

Air Barrier Continuity

Water Barrier Continuity

Balanced Vapor Profile

Devil in the Details

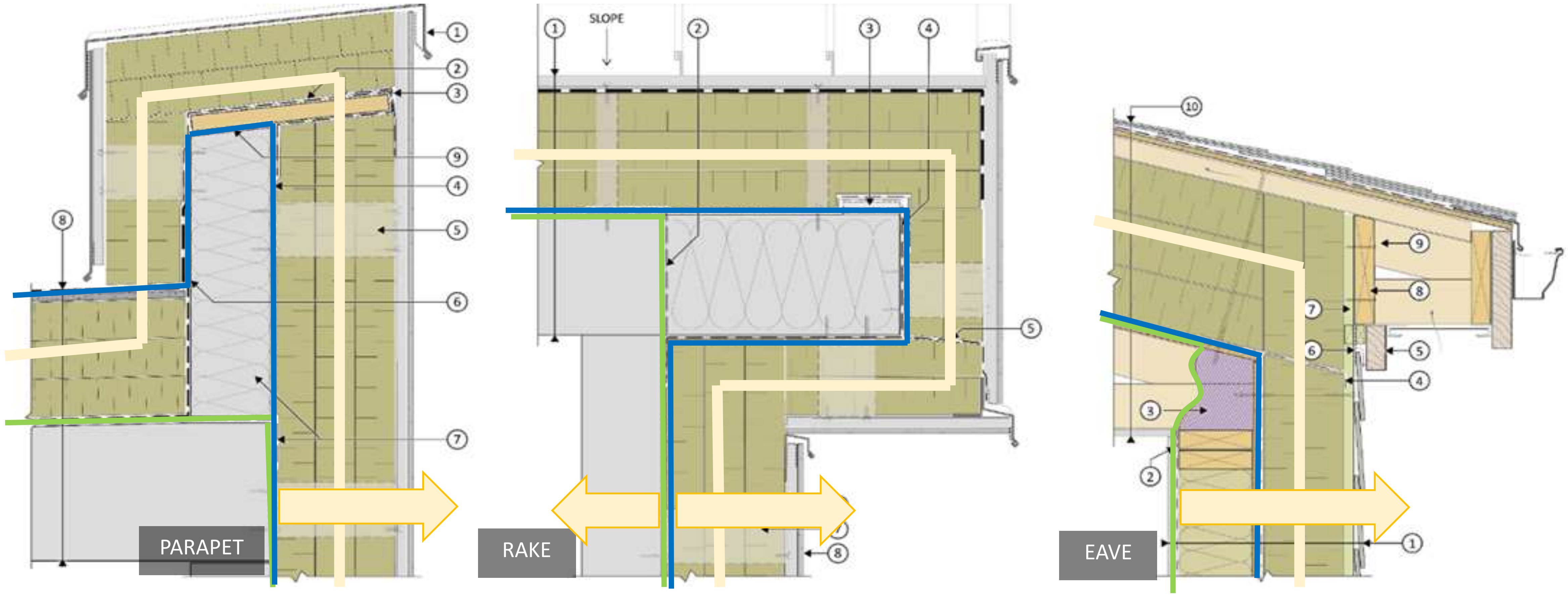
- High Performance
- Barrier Continuity
- Balanced Vapor Profile

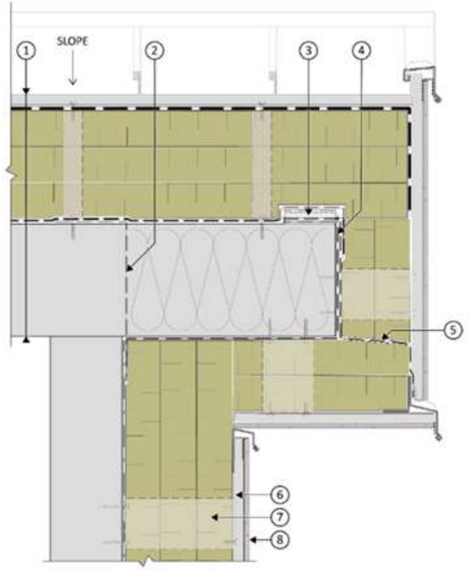
Thermal Barrier Continuity

Air Barrier Continuity

Water Barrier Continuity

Balanced Vapor Profile





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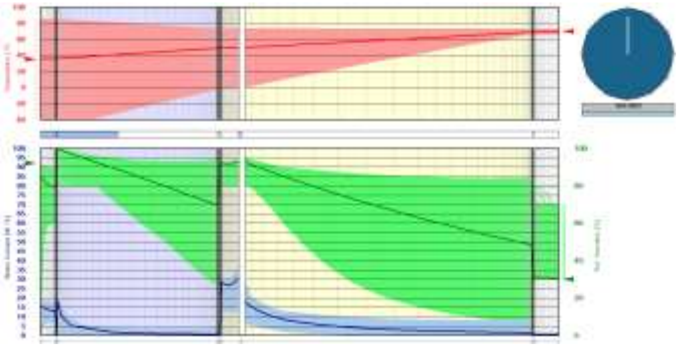
Thank You



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Building Envelope Design for Thermal Resiliency