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Webinar Series

Building Science for Net Zero Energy Wood-frame Walls:

1. **Exterior Insulation Selection**
2. **Detailing with Exterior Insulation**
3. **Detailing with Deep & Double Stud Walls**

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Goal Today

Understand how to design durable wood-frame walls with any type or thickness of exterior insulation

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Outline

- Wall Target R-value
- Exterior Insulation Ratios
- Considerations for:
  - Vapour Control
  - Airflow Control
  - Water Control
  - Cladding Attachment
- Additional Resources

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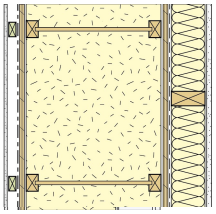
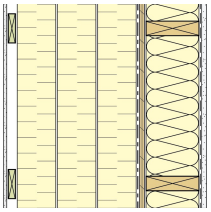
High R-value Wood-frame Walls – 2 Fundamental Approaches

Stuff It: Deep/Double Stud



Wrap It: Exterior Insulated



Good News! Walls with more exterior insulation become more durable as insulation levels increase (any type of insulation)

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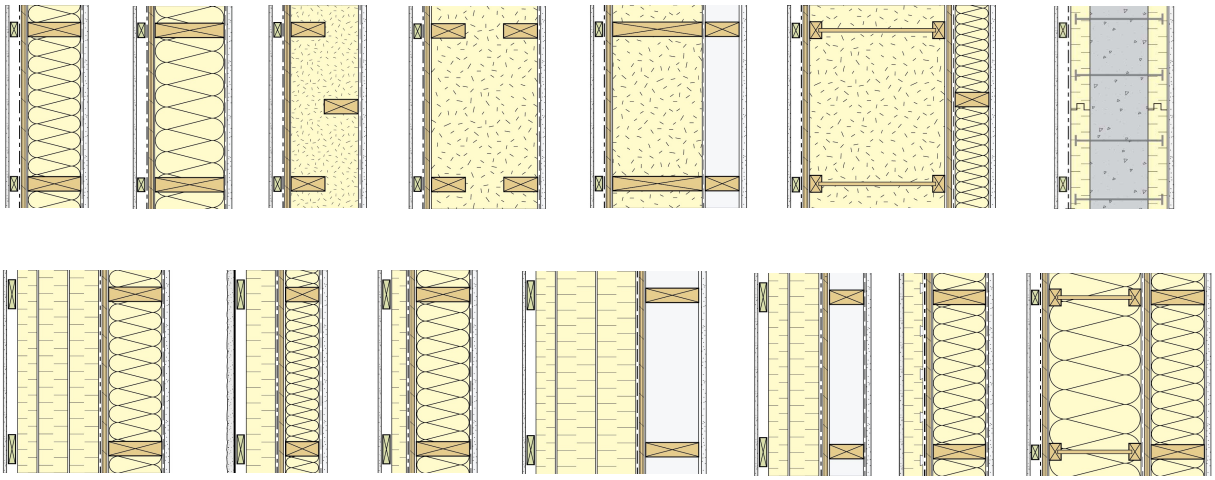
Overwhelming Number of Assembly Options & Material Choices



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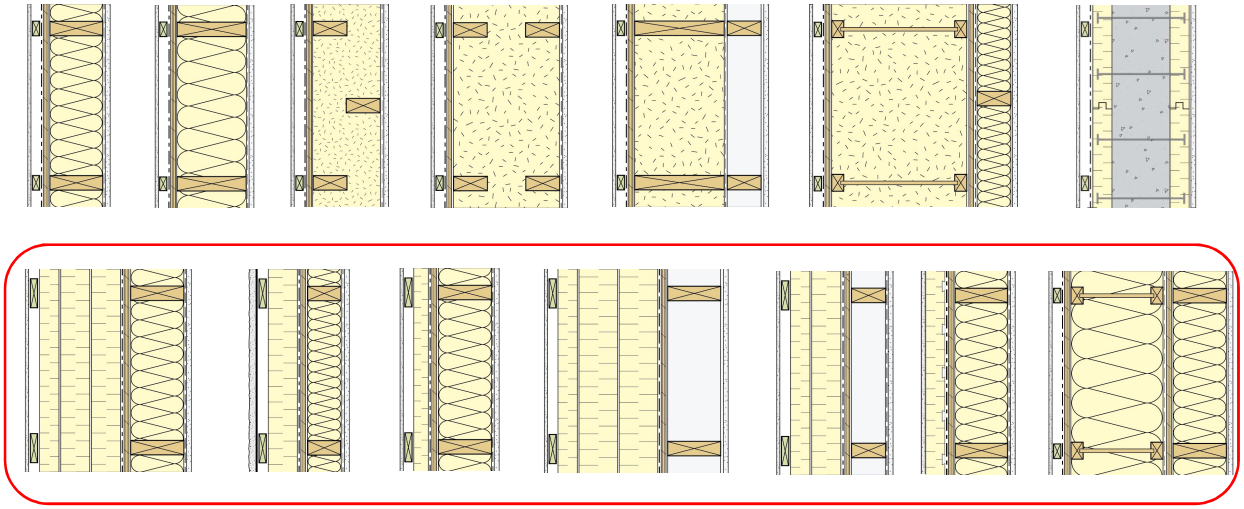
Today & Webinar #2



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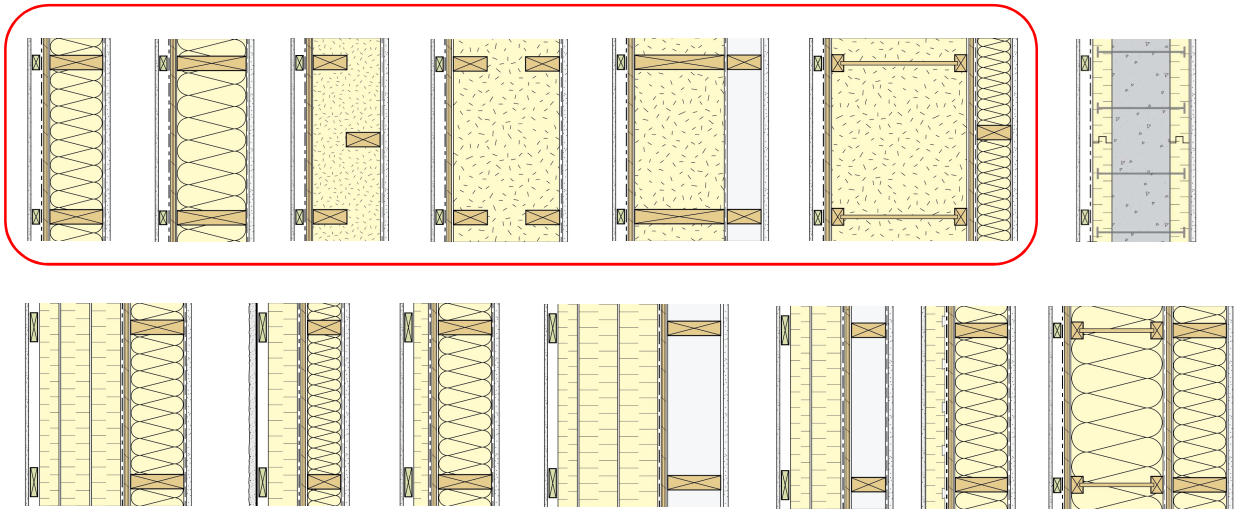
Webinar #3



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Decision Criteria – How do you Choose an Assembly & Materials?

Cost Efficiency / Affordability ★★★★★

Constructability & Detailing ★★★★★

Performance (R-value/Airtightness) ★★★★★

Moisture Durability & Resilience ★★★★★

Sustainability & Material Selection ★★★★★

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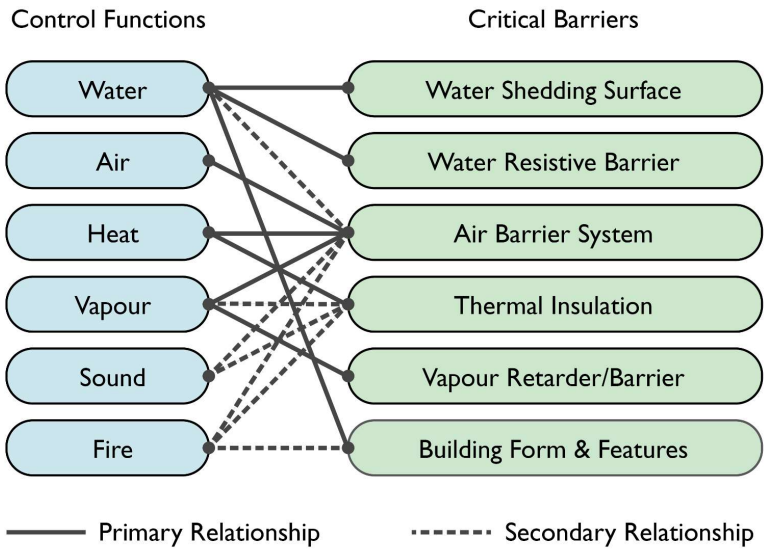
Building Science Design Criteria



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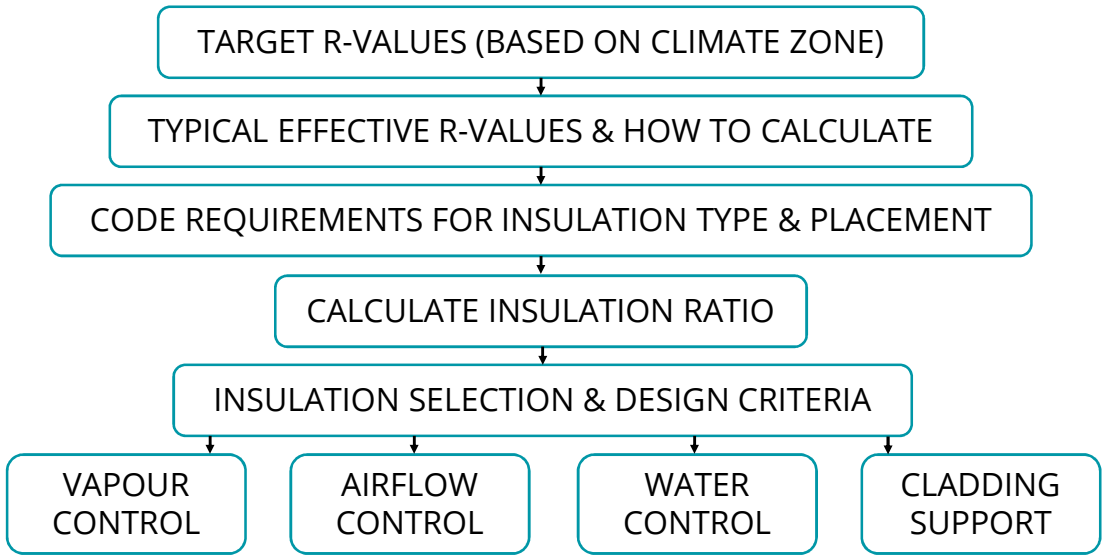
Exterior Insulation Selection & Detailing Flow-Chart



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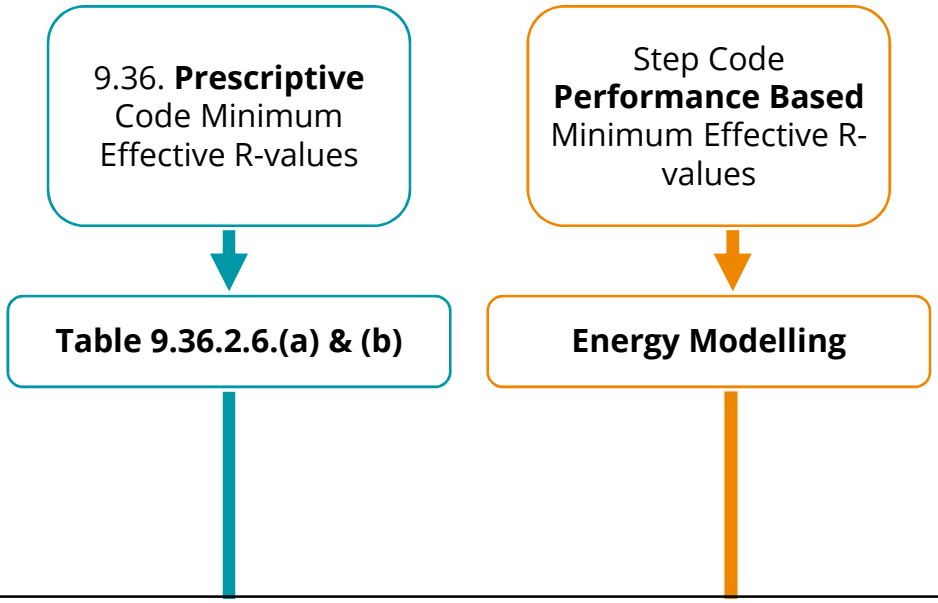
Target Wall R-values?



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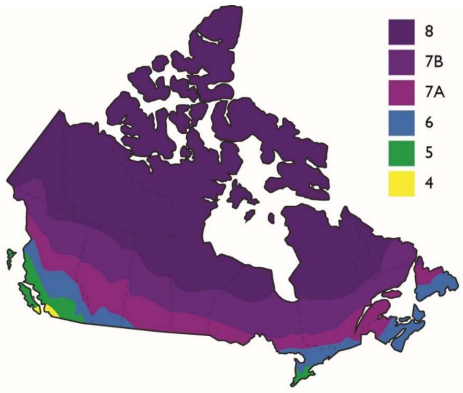
Part 9 Code Minimum Wall R-values

Canadian Climate Zones



7B& 8 are only Climate Zones where the current 9.36 Minimum R-value is greater than a 2x6 wall with R-20, R-22 or R-24 Insulation

9.36.2.6. Minimum Effective R-values per Climate Zone

	Zone 4	Zone 5	Zone 6	Zone 7A	Zone 7B	Zone 8
Without HRV	15.8	17.5	17.5	17.5	21.9	21.9
With HRV	15.8	16.9	16.9	16.9	17.5	17.5

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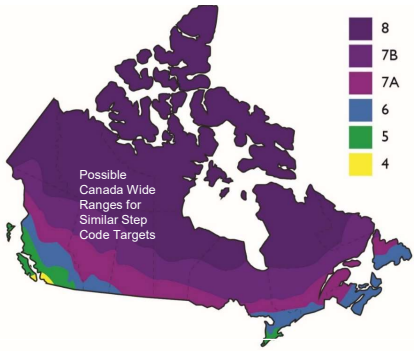
Potential BC Energy Step Code Target R-values for Walls

BC Climate Zones

8	> 7,000 HDD
7B	6,000 to 6,999 HDD
7A	5,000 to 5,999 HDD
6	4,000 to 4,999 HDD
5	3,000 to 3,999 HDD
4	< 3,000 HDD



Expected Effective R-values Based on Step Code Performance Targets per Climate Zone

	Zone 4	Zone 5	Zone 6	Zone 7A	Zone 7B	Zone 8
Step 1	16	16 – 18	16 – 18	18 – 22	18 – 22	18 – 22
Step 2	16 – 22	16 – 60	18 – 60	18 – 60	18 – 60	18 – 60
Step 3	16 – 22	16 – 60	18 – 60	18 – 60	18 – 60	18 – 60
Step 4	16 – 25	18 – 60	18 – 60	22 – 60	22 – 60	22 – 60
Step 5	22 – 40	30 – 60	30 – 60	30 - 60+	30 - 60+	30 - 60+

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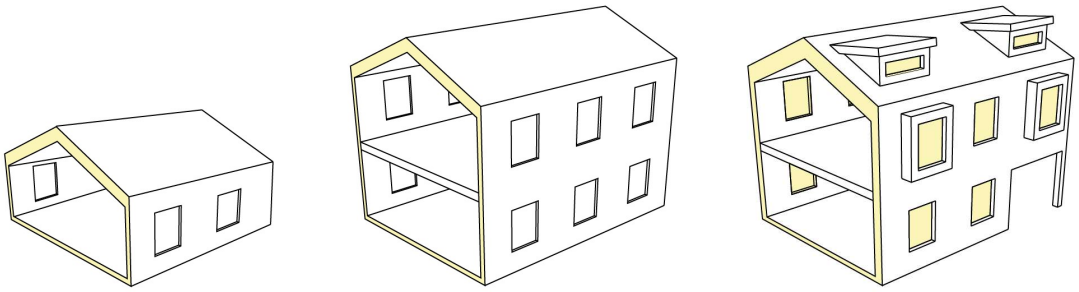
Why the Big Range of Potential Wall R-values for the Same Target?



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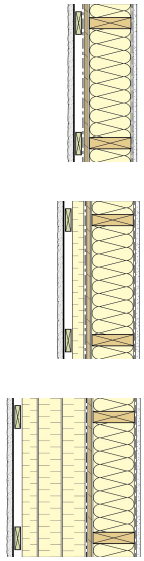
Effective R-values of Walls with Exterior Insulation

Effective R-values of Split-Insulated Wall Assemblies

Inches of Exterior Insulation	2x4 with R-12 Batt Insulation			2x6 with R-19 Batt Insulation		
	R-value of Exterior Insulation			R-value of Exterior Insulation		
	R-4/in.	R-5/in.	R-5.6/in.	R-4/in.	R-5/in.	R-5.6/in.
0.0	11.3	11.3	11.3	16.2	16.2	16.2
0.5	13.3	13.8	14.1	18.2	18.7	19.0
1.0	15.3	16.3	16.9	21.2	21.2	21.8
1.5	17.3	18.8	19.7	23.7	23.7	24.6
2.0	19.3	21.3	22.5	26.2	26.2	27.4
2.5	21.3	23.8	25.3	28.7	28.7	30.2
3.0	23.3	26.3	28.1	31.2	31.2	33.0
4.0	27.3	31.3	33.7	36.2	36.2	38.6
5.0	31.3	36.3	39.2	41.2	41.2	44.2
6.0	35.3	41.3	44.9	46.2	46.2	49.8
7.0	39.3	46.3	50.5	51.2	51.2	55.4
8.0	43.3	51.3	56.1	56.2	56.2	61.0



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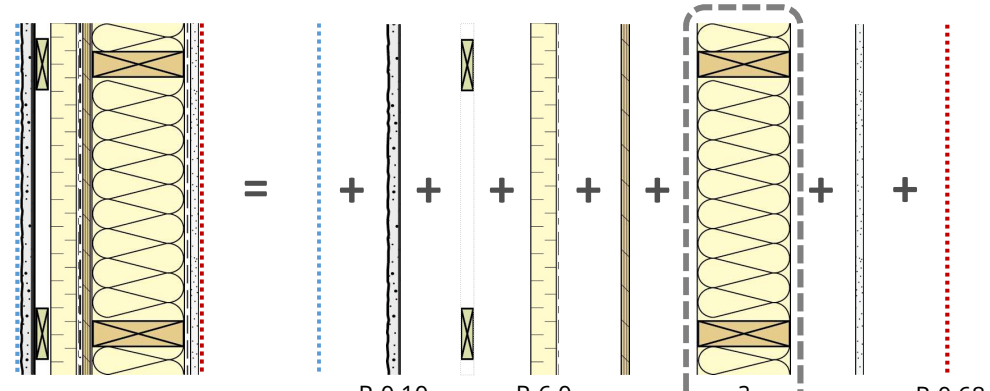
What is an Effective R-value?

Isothermal Planes



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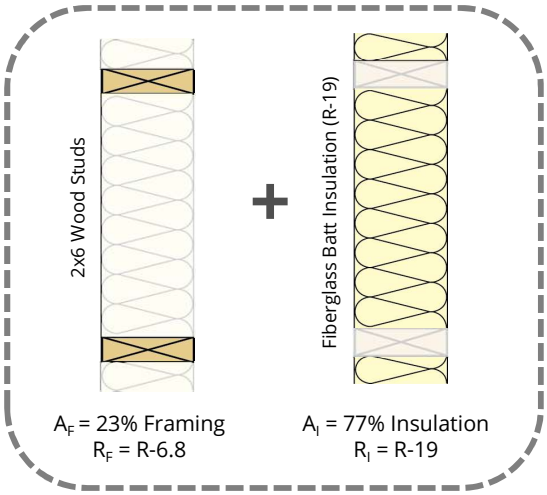
What is an Effective R-value?

Parallel Paths

R-Value =



$$\frac{100}{\left(\frac{A_F}{R_F}\right)+\left(\frac{A_I}{R_I}\right)} = \frac{100}{\left(\frac{23}{6.8}\right)+\left(\frac{77}{19}\right)}$$

= R-13.4

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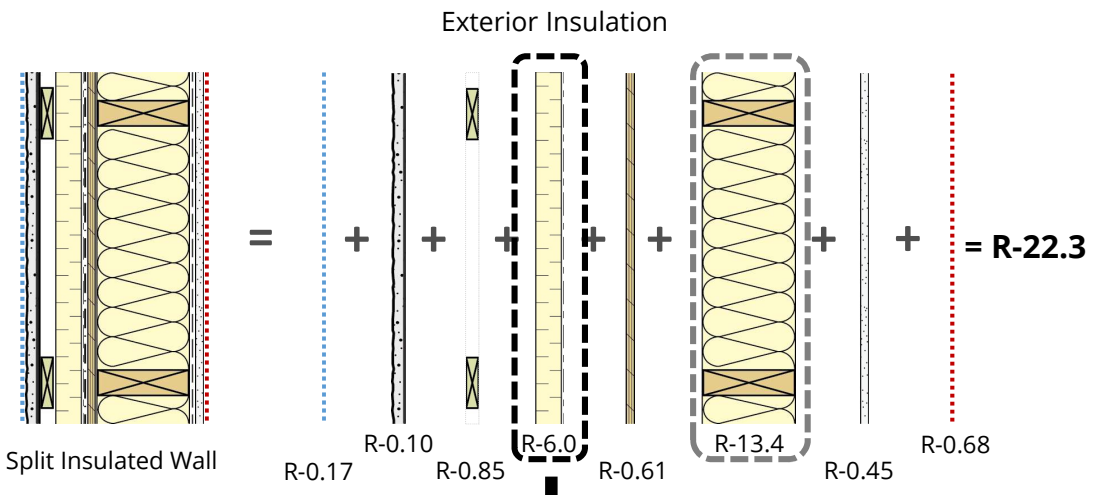
What is an Effective R-value?



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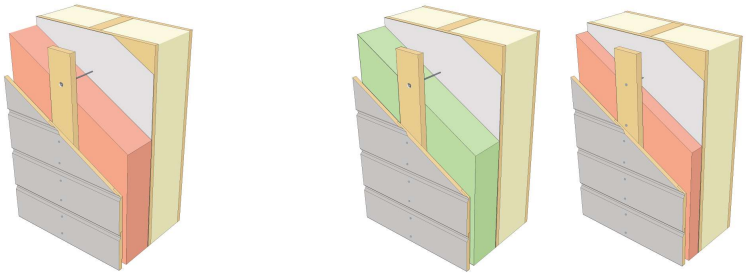
Exterior Insulation Ratios

Impermeable Insulation

Relatively **Permeable** Insulation



≤ 60 ng/Pa·s·m² (≤ 1 US Perm)

> 60 ng/Pa·s·m² (> 1 US Perm)

Triggers Code Requirement for Placement/Ratio

Does Not Trigger Code Requirement for Placement/Ratio

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Vapour Permeance of Various Exterior Insulations

Dry Cup Permeance (US Perms)

Insulation Type	1"	2"	3"	4"	5"	6"	7"	8"
XPS	0.9	0.4	0.3	0.2	0.2	0.1	0.1	0.1
Closed Cell Sprayfoam	1.7	0.9	0.6	0.4	0.3	0.3	0.2	0.2
Polyiso with Paper Facers	2.0	1.0	0.7	0.6	0.4	0.4	0.3	0.3
Polyiso with Foil Facers	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
EPS (Type 1) w/o facers	3.5	1.8	1.2	0.9	0.7	0.6	0.5	0.4
Wood Fiber Board	9.1	4.6	3.0	2.3	1.8	1.5	1.3	1.1
Open Cell Sprayfoam	60.2	30.1	20.1	15.1	12.0	10.0	8.6	7.5
Rigid Mineral Wool	88.8	49.5	29.6	22.2	17.8	14.8	12.7	11.1
Cellulose	92.3	46.1	30.8	23.1	18.5	15.4	13.2	11.5
Rigid Fiberglass	145.1	72.5	48.4	36.3	29.0	24.2	20.7	18.1

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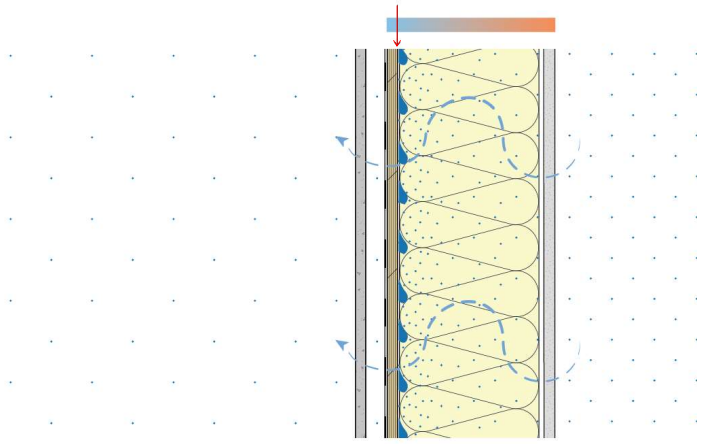
Why Does the Insulation Type and Ratio Matter?



During wintertime, vapour flow occurs outwards through an insulated wood-frame wall. Increased flow in homes with high RH and colder exterior

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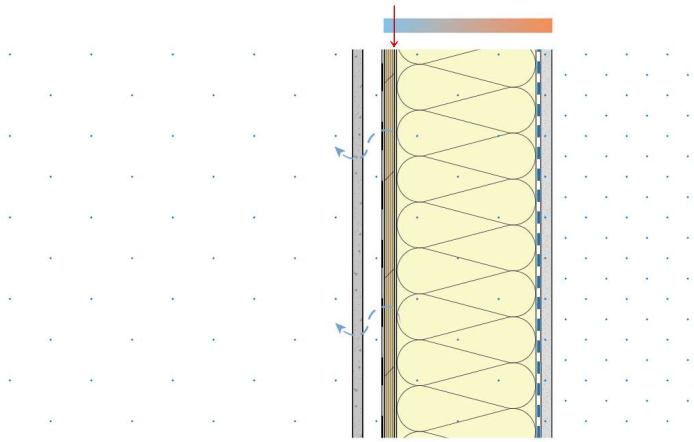
Why Does the Insulation Type and Ratio Matter?



Adding a vapour retarder at the interior slows the outward flow enough so that condensation does not occur within the cavity

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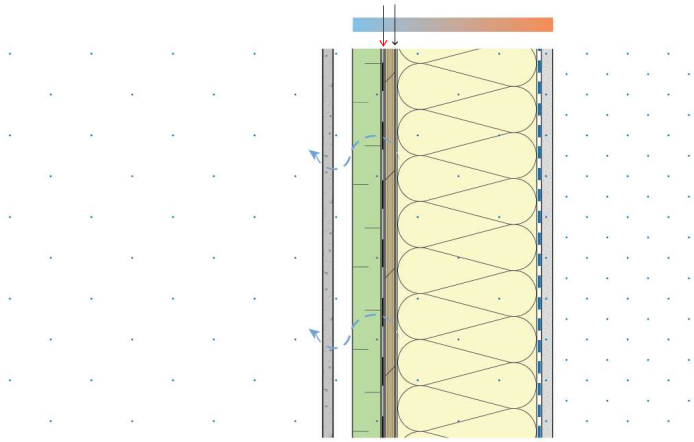
Why Does the Insulation Type and Ratio Matter?



Adding any type of exterior insulation warms up the sheathing, lowering the potential for vapour diffusion condensation. Permeable exterior insulation allows vapour to continue to flow through to the exterior

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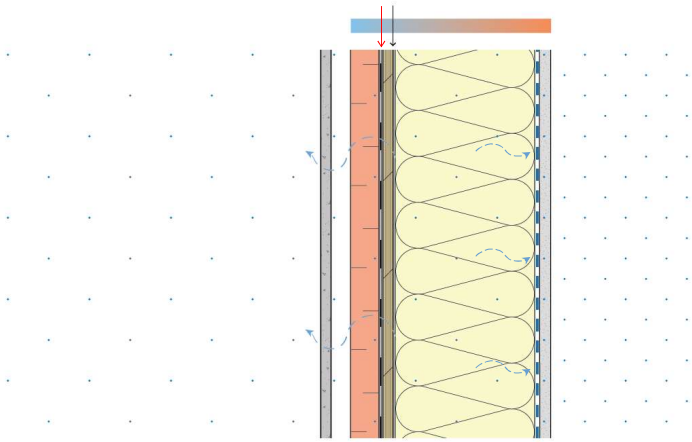
Why Does the Insulation Type and Ratio Matter?



Impermeable insulation slows down this outward vapour flow meaning that the control of moisture into the cavity becomes more critical to manage, though without trapping moisture that may enter

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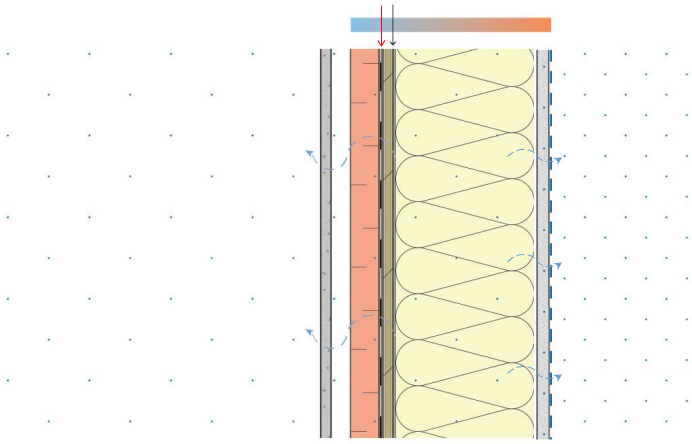
Why Does the Insulation Type and Ratio Matter?



With impermeable exterior insulation it is desirable to allow for drying inwards to enhance durability and provide some ability for the wall to dry out – hence removal of poly and replacement with higher permeance membrane. BUT need enough exterior insulation so that this is safe to do so

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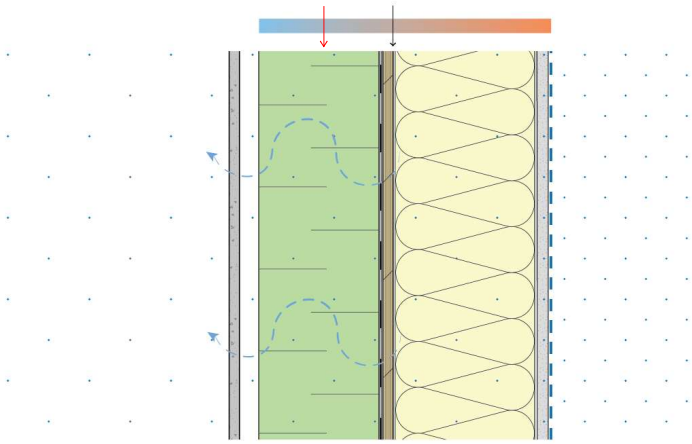
Why Does the Insulation Type and Ratio Matter?



Vapour permeable exterior insulation allows for outward diffusion drying, and therefore it isn't as critical to open up the interior to allow for inward drying

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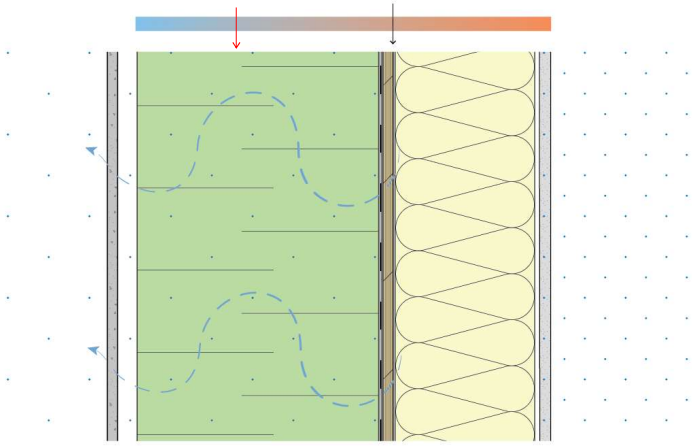
Why Does the Insulation Type and Ratio Matter?

Net Zero Ready Walls are at or approaching these types of ratios



With high ratio thicknesses of any type of exterior insulation the sheathing will be about the interior dewpoint and therefore not at risk of vapour diffusion condensation or air leakage condensation – allows for high degree of design flexibility and redundancy

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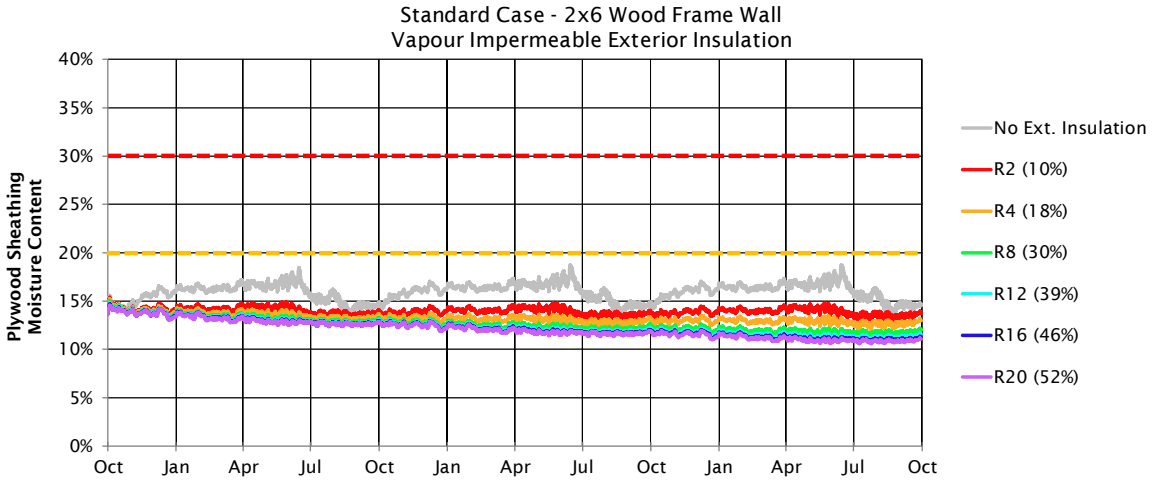
Adding Exterior Insulation Makes Walls Dryer



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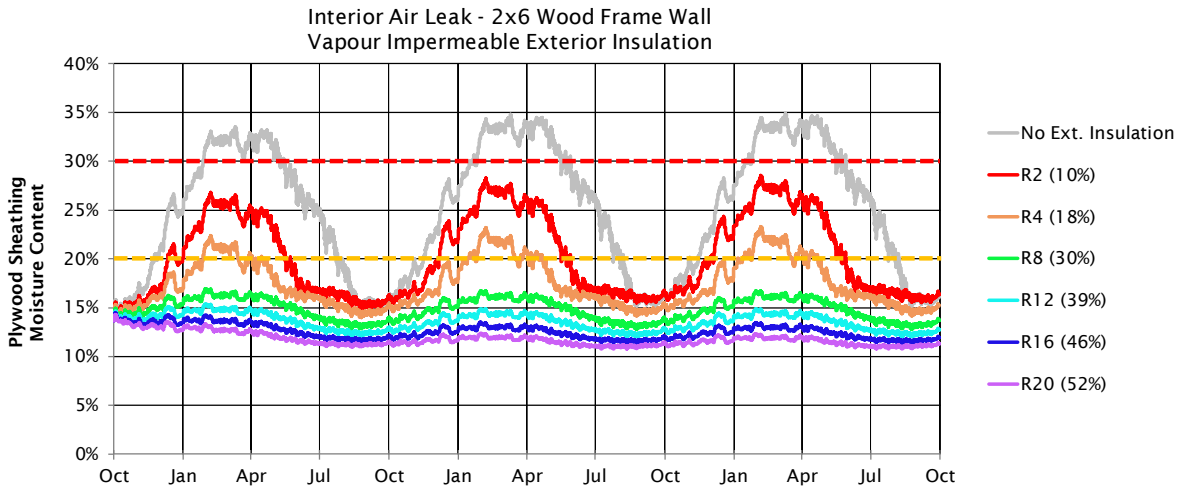
Adding Exterior Insulation Lowers Air Leakage Risk



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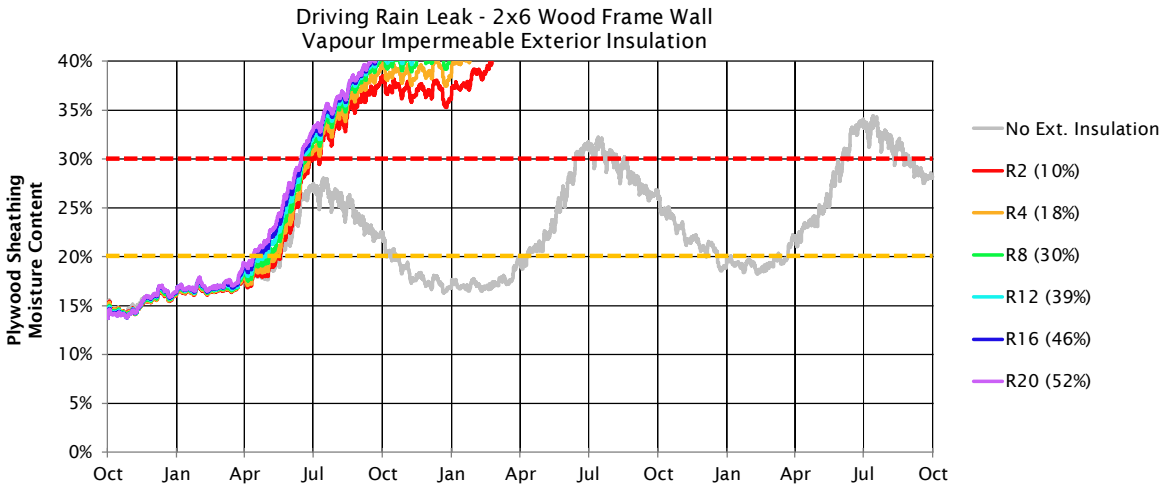
Exterior Insulation Permeance Matters for Outward Drying – Watch Detailing for Water



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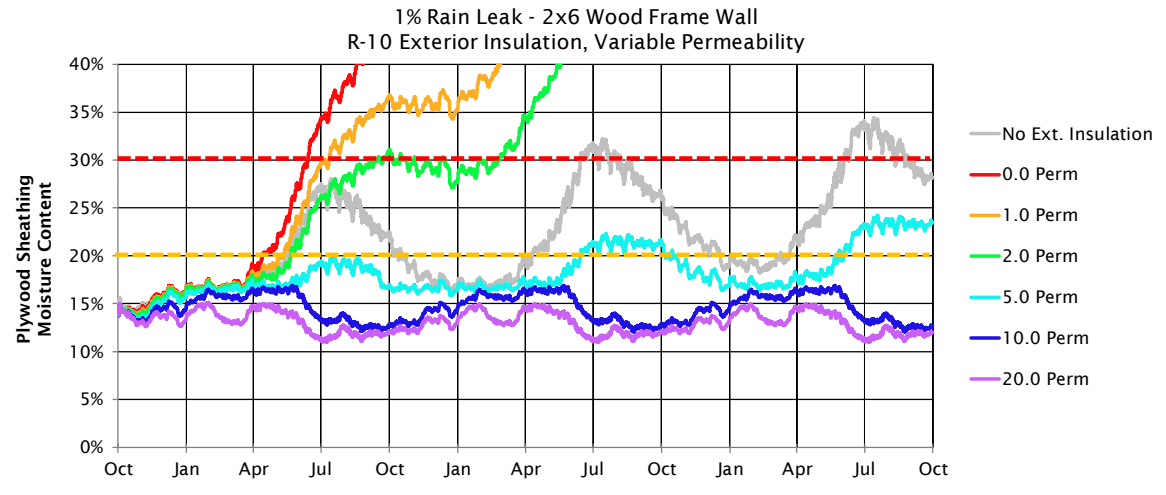
When does the Difference between Permeable and Impermeable Exterior Insulation Matter?



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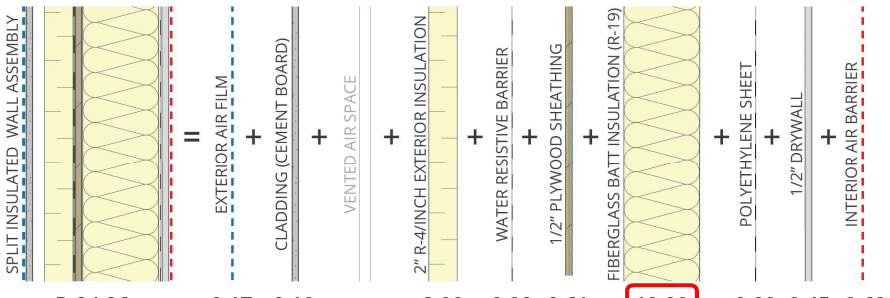
Calculating Insulation Ratios

Calculate Exterior to Interior Insulation Ratios



Line of Low Air and Vapour Permeance

Use Nominal

Σ TOTAL R-29.0 | Σ OUTBOARD R-8.9 | Σ INBOARD R-20.1

$$\text{Outboard to Inboard} = \frac{\Sigma \text{ OUTBOARD}}{\Sigma \text{ INBOARD}} = \frac{\text{R-8.9}}{20.1} = \mathbf{0.44}$$

$$\text{Outboard to Total} = \frac{\Sigma \text{ OUTBOARD}}{\Sigma \text{ TOTAL}} = \frac{\text{R-8.9}}{29.0} = \mathbf{0.31}$$

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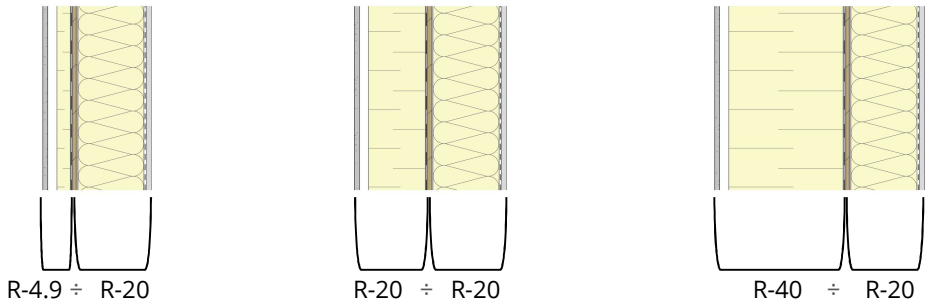
Example Insulation Ratios

Example Split-Insulated Assemblies & Insulation Ratios



Outboard to Inboard	= **0.24**	= **1.0**	= **2.0**

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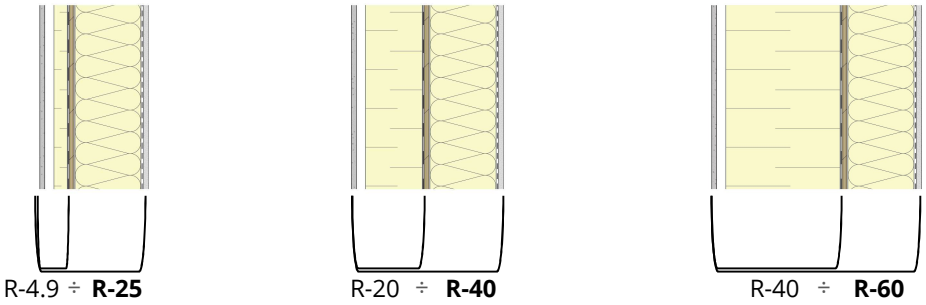
Example Insulation Ratios

Example Split-Insulated Assemblies & Insulation Ratios



	R-4.9 ÷ **R-25**	R-20 ÷ **R-40**	R-40 ÷ **R-60**
Outboard to Inboard	= **0.24**	= **1.0**	= **2.0**
Outboard to Total	= **0.20**	= **0.5**	= **0.67**

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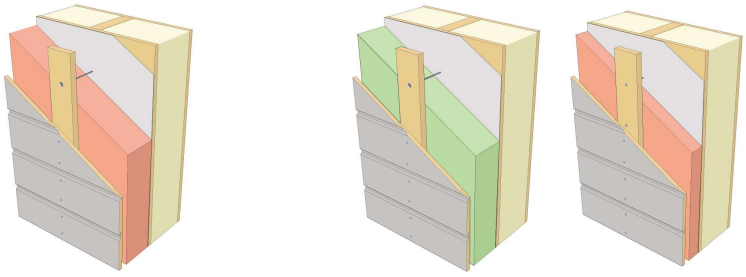
Exterior Insulation Ratios

Impermeable Insulation

Relatively **Permeable** Insulation



≤ 60 ng/Pa·s·m^2
(≤ 1 US Perm)

> 60 ng/Pa·s·m^2
(> 1 US Perm)

Triggers Code Requirement for Placement/Ratio

Does Not Trigger Code Requirement for Placement/Ratio (use recommended ratios)

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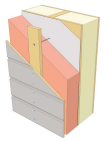
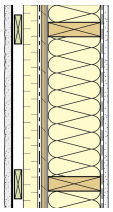
Code Minimum Insulation Ratios with Impermeable Exterior Insulation

Required Ratio of Outboard to Inboard Thermal Resistance from NBC 9.25.5.2

Heating Degree Days	Minimum Ratio of Total Thermal Resistance Outboard of Material's Inner Surface to Total Thermal Resistance Inboard of Materials Inner Surface	Outboard to Total Ratio
Up to 4999	0.20	0.17
5000 – 5999	0.30	0.23
6000 – 6999	0.35	0.26
7000 – 7999	0.40	0.29
8000 – 8999	0.50	0.33
9000 – 9999	0.55	0.35
10000 – 10999	0.60	0.38
11000 – 11999	0.65	0.39
12000 or higher	0.75	0.43





Note: Ratios are based on 1 US Perm vapour retarder located on the warm side of the insulation, wintertime conditions, and indoor relative humidity of 35%

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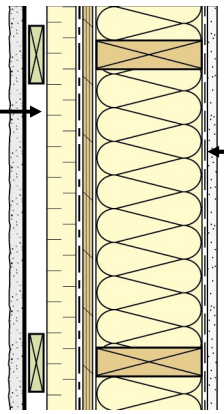
What Types of Walls does this Table Generate?

Foam plastic insulation less than 1 US perm and airtight board material*

Generally 1" to 2" of exterior insulation is sufficient

Table does not discuss WRB placement/water control



1 US Perm interior vapour retarder (VB Paint on drywall or smart vapour retarder)

Interior surface still airtight

Low indoor RH (mechanical ventilation/HRV)

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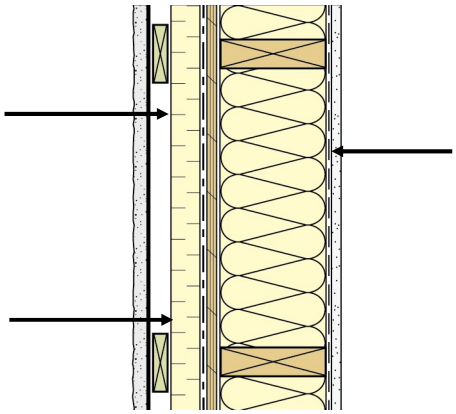
What Types of Walls Aren't Covered by this Table?

Any type of exterior insulation with a vapour permeance >1 US Perm & more permeable than inner vapour control layer



0.01 US Perm Polyethylene Vapour Barrier & (or other vapour barrier <1 US perm)

Part 9 of NBC does not cover WRB placement w/ exterior insulation

This wall is allowed by the NBC and doesn't trigger insulation ratio requirements.

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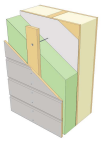
Recommended Insulation Ratios for Design Flexibility

Recommended Ratio of Outboard to Total Thermal Resistance to Limit Condensation Risk



Winter Design Temperature	Indoor Wintertime Relative Humidity				
	20%	30%	40%	50%	60%
0	0.00	0.12	0.32	0.47	0.60
-10	0.23	0.40	0.54	0.64	0.73
-20	0.41	0.55	0.65	0.73	0.80
-30	0.53	0.64	0.72	0.78	0.84
-40	0.66	0.70	0.76	0.82	0.86

Note: Ratios assume no interior vapour control layer and allow for any type of exterior insulation, sheathing or WRB on the exterior of the cavity, as they raise the temperature of the sheathing above the indoor dewpoint and lower the risk of vapour diffusion/air leakage condensation

Assess at Average Wintertime conditions and expected indoor RH levels

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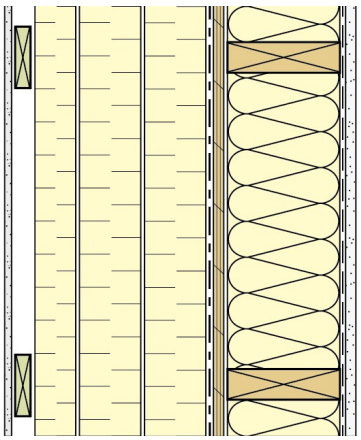
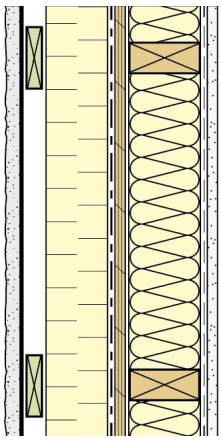
What Types of Walls does this Table Generate?





Any type of exterior insulation – permeable or impermeable

Flexibility for interior vapour control and air barrier placement within wall

Greater thicknesses of exterior insulation where indoor RH higher

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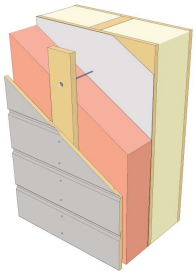
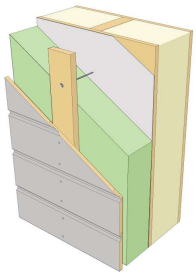
Exterior Insulation Types

Selecting Exterior Insulation

Impermeable

Vapour **Permeable**





Rigid Foam Insulation

XPS | Polyiso | EPS* | ccSPF

Rigid/Semi-rigid Fibrous Insulation

Mineral Wool | Wood Fibre | Cellulose Fibre | Fibreglass

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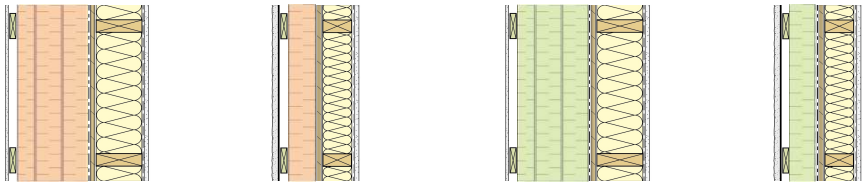
Safe or Cautionary Insulation Ratios? – Table B

Condensation risk due to **vapour** and **airflow** associated with selected exterior insulation ratio, indoor and outdoor conditions, and use of space

Safe (High Ratios)	**Cautionary** (Low Ratios)	**Safe** (High Ratios)	**Cautionary** (Low Ratios)



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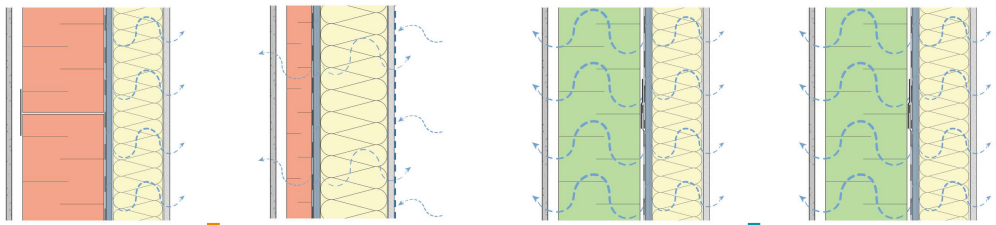
Guidance for Vapour Control

Vapour Control		**Vapour Control**	
Vapour flow is controlled by the exterior insulation Vapour diffusion drying to interior is desirable **No interior vapour control layer necessary**	Facilitate some inward drying, while still limiting outward vapour diffusion Vapour retarder or smart vapour retarder material is recommended	Vapour flow is controlled by the sheathing Vapour diffusion drying occurs both outwards and inwards when conditions permit **No interior vapour control layer necessary**	Vapour diffusion drying occurs outwards and possibly to the interior depending on interior vapour control Vapour retarder or smart vapour retarder material may be used



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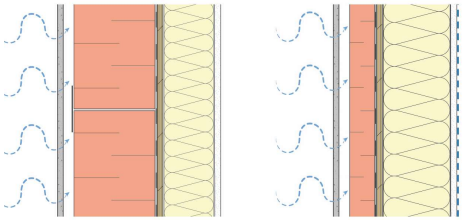
Guidance for Vapour Control

Inward Vapour Control?

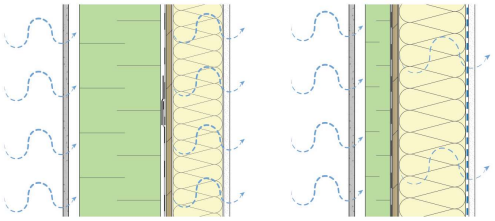
Inward vapour flow is limited by the rainscreen space the cladding and the exterior insulation



Inward Vapour Control?

Inward vapour flow is limited by the rainscreen space behind the cladding

Vapour diffusion drying occurs both outwards and inwards when conditions permit



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Guidance for Air Flow Control

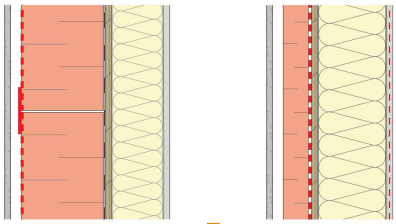
Airflow Control

Exterior or mid-wall approaches most desirable

- Taped/sealed foam insulation
- Sealed Sheathing
- Sealed Sheathing Membrane

Risk of convective looping within cavity, provide some interior airtightness

- Sealed Sheathing
- Sealed Sheathing Membrane
- **Airtight drywall to limit convection potential**



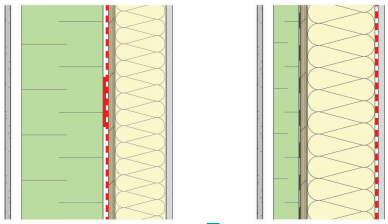
Airflow Control

Mid-wall sheathing air barrier approaches most desirable

- Sealed Sheathing
- Sealed Sheathing Membrane
- Interior AB possible

Risk of convective looping within cavity, provide some interior airtightness

- Sealed Sheathing
- Sealed Sheathing Membrane
- Sealed Polyethylene, Drywall, or Interior Sheathing



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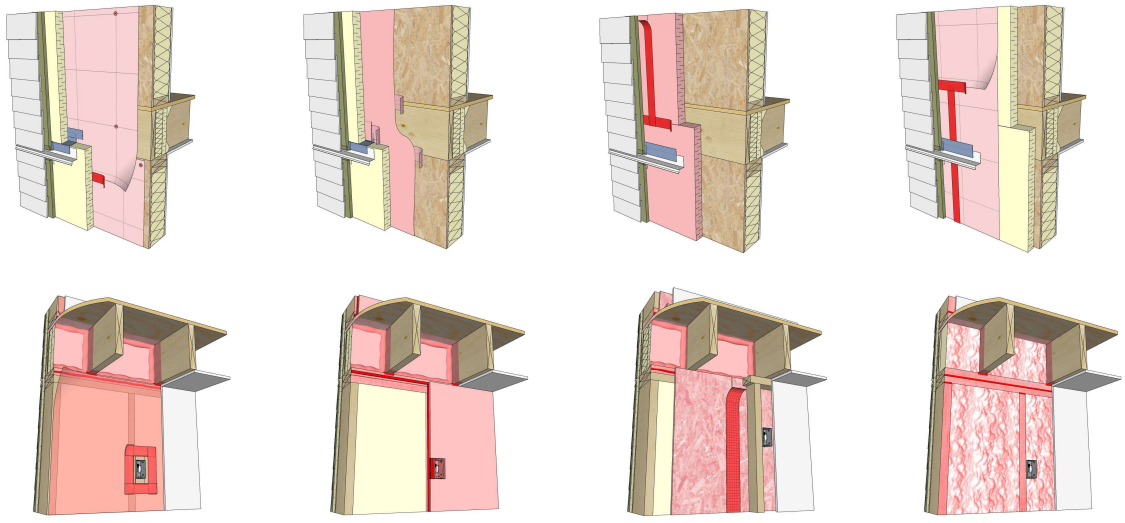
Air Barrier System Options



General rule of thumb – maintain some degree of interior airtightness with exterior air barriers until safe insulation ratios are achieved

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Guidance for Water Control

Water Control

Water Control

Selection of Water Resistive Barrier (WRB) and rainscreen cladding recommendations based on exterior insulation type

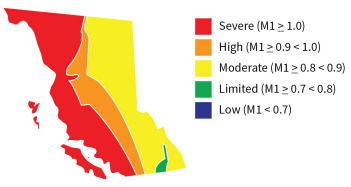
Low to Moderate Moisture Index

High Moisture Index or wetting risk

Moisture tolerant permeable insulation

Moisture sensitive permeable insulation

BC MOISTURE INDEX



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Guidance for Water Control

Low to Moderate Moisture Index	High Moisture Index or wetting risk	Moisture tolerant permeable insulation	Moisture sensitive permeable insulation
• Taped/sealed foam • All details/flashings on exterior of foam • Rainscreen recommended even when not required by code	• Taped/sealed foam with WRB behind • Consider providing **small drainage space** between foam and WRB • Rainscreen assembly required per code	• WRB behind exterior insulation or applied over exterior insulation • All details/flashings behind insulation, though without creating wetting pathway	• WRB installed over exterior insulation • All details/flashing on exterior of insulation

Rainscreen recommended even when not required by code

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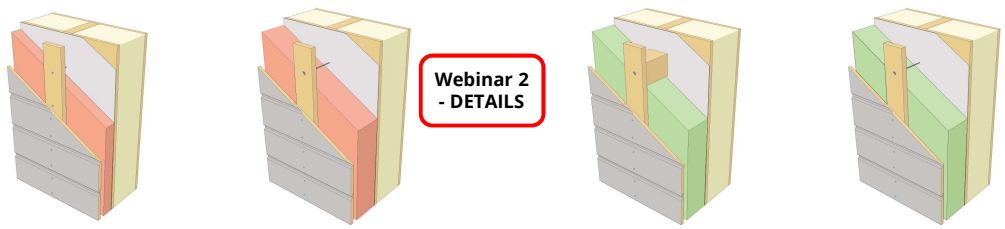
Guidance for Cladding Attachment

Cladding Attachment		Cladding Attachment	
Selection of cladding attachment based on insulation type			
≤ 2 inches thick	> 2 inches thick	Semi-Rigid	Rigid
Nail/screw directly through insulation or use strapping and long nails/screws	Use vertical strapping and long screws	Clips or blocking through exterior insulation	Per guidance at left for impermeable rigid insulation



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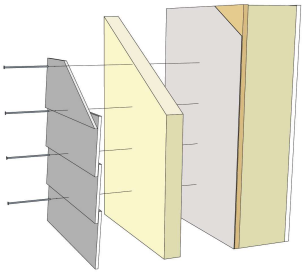
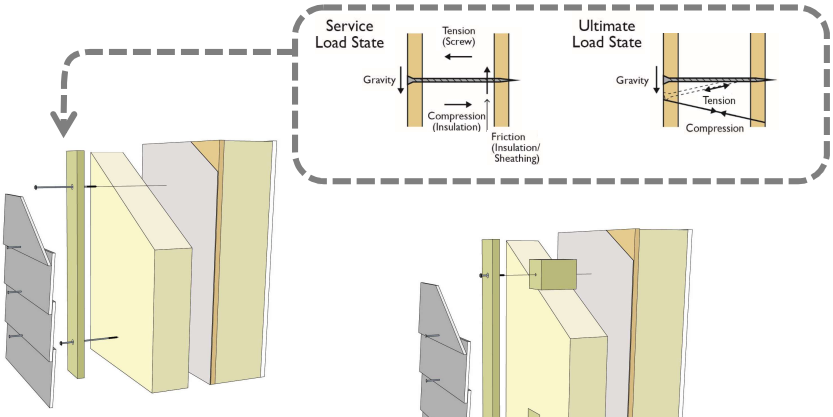
Cladding Attachment – Long Screws Through Exterior Insulation



Cladding fasteners (nails) directly through rigid insulation (for up to 2" and light claddings)



Long screws through vertical treated strapping and any depth of exterior rigid insulation creates truss – short cladding fasteners into vertical strapping

Rigid shear block type connection through insulation, short cladding fasteners into vertical strapping

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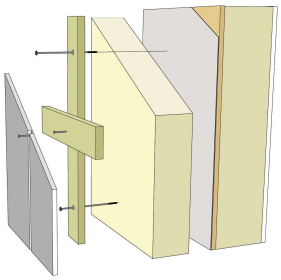
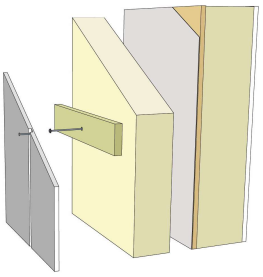
Cladding Attachment – Vertical Cladding

Typical:



Treated Cross Strapping

Dry Regions / Low Moisture Index Only:



Treated Horizontal Strapping

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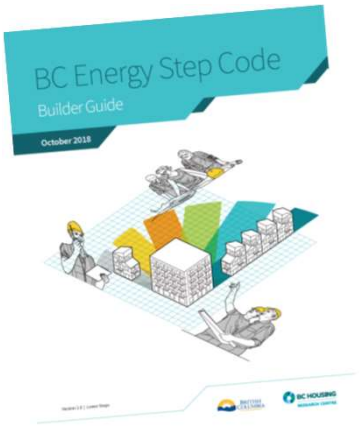
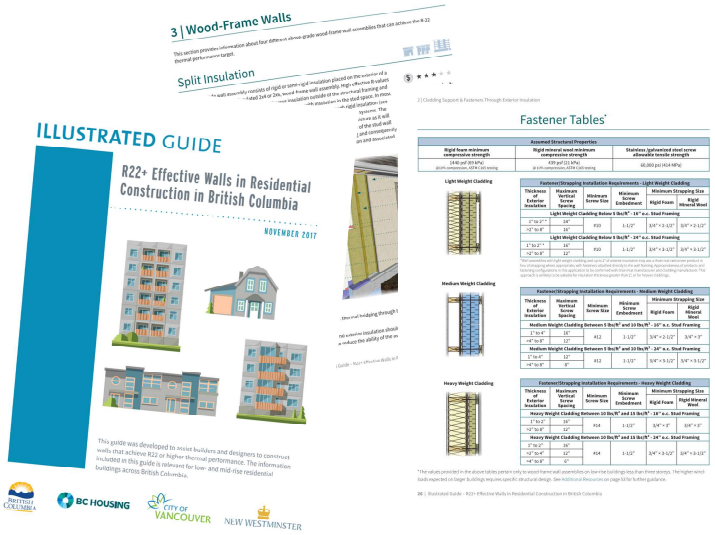
Additional Resources





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