Natural Resources Canada
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FIELD EVALUATION OF HYGROTHERMAL PERFORMANCE AND CONSTRUCTABILITY OF A VACUUM-INSULATED, THIN WOOD-FRAME WALL ASSEMBLY

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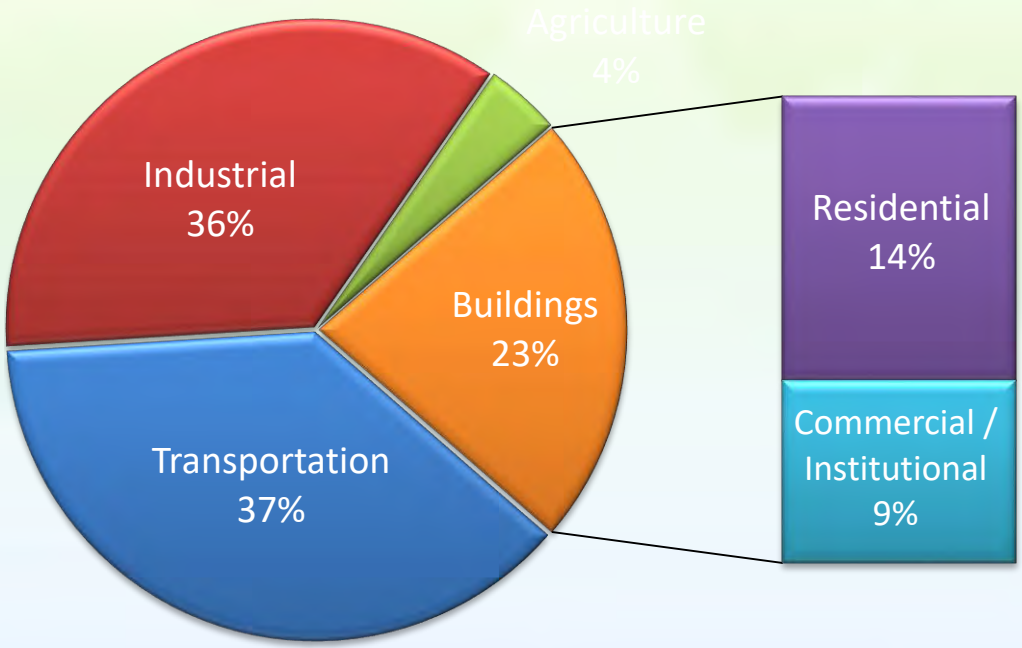
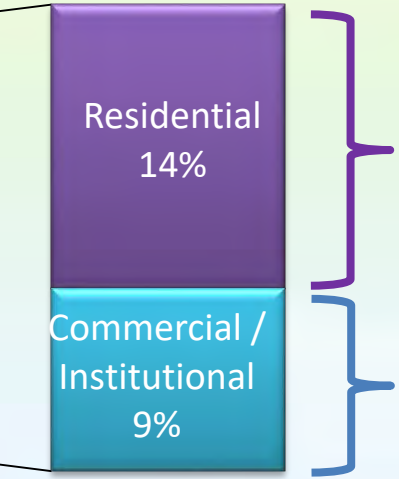
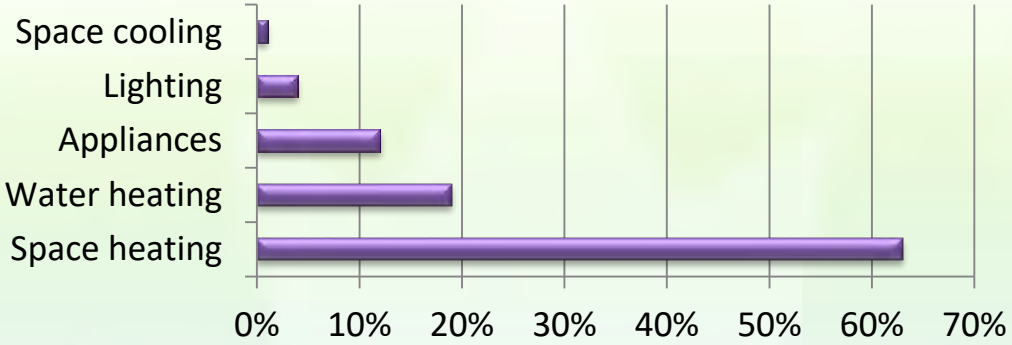
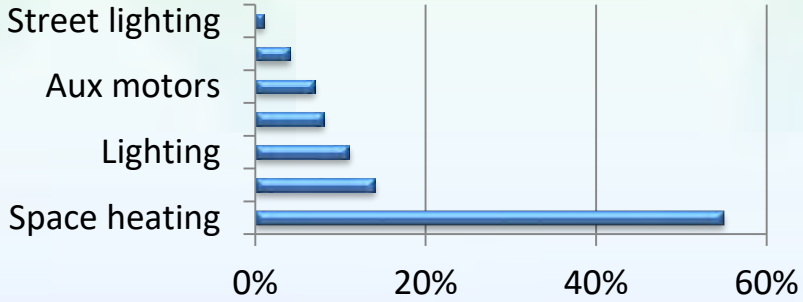
Canada's Energy Use GHG Emissions



Breakdown by End Use





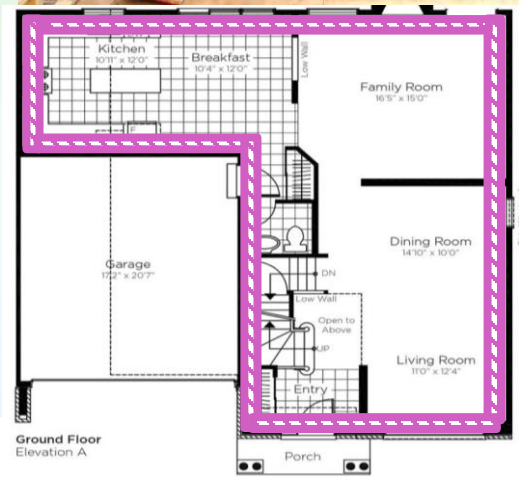


R-2000, NZE, Passive House Wall Assemblies

Location	Guelph	Calgary	Edmonton	Ottawa	Montreal	Ottawa	Ottawa	Vancouver
Form	Detached	Detached	Detached	Attached	MURB	Detached	MURB	MURB
Year built	2015	2015	2015	2015	2015	2016	2016	2016
HDD [18°C]	3890	5000	5120	4500	4200	4500	4500	
Wall assembly	R24 batt + R15 XPS (3")	R24 + R22.5 XPS (4.5")	2x4 double stud c/w 12" cellulose	R24 + R10 XPS (2")	R24 + R10 XPS (2")	2x6 11" stand-off 2x4	Light gauge steel + 12" SIP	2x6 +R20
Effective thermal resistance [K·m²/W (ft²·°F·h/Btu)]	RSI 6.5 (R37)	RSI 7.5 (R43)	RSI 7.0 (R40)	RSI 5.5 (R31)	RSI 5.1 (R29)	RSI 16.4 (R93)	RSI 9.5 (R54)	RSI 7.0 (R40)
Assembly thickness [mm (inches)]	216 (8.5)	254 (10)	305 (12)	190 (7.5)	190 (7.5)	675 (26.5)	380 (14.5)	300 (11.5)

Need

- High-performance homes require higher levels of insulation
- Current approaches may not be appropriate for production builders because they reduce floor area by 6-8% ($25-35k)
- Industry needs cost competitive, factory-built, high-insulating thin walls for larger market adoption



= 16m² Lost floor space (7%) ($25-35k)

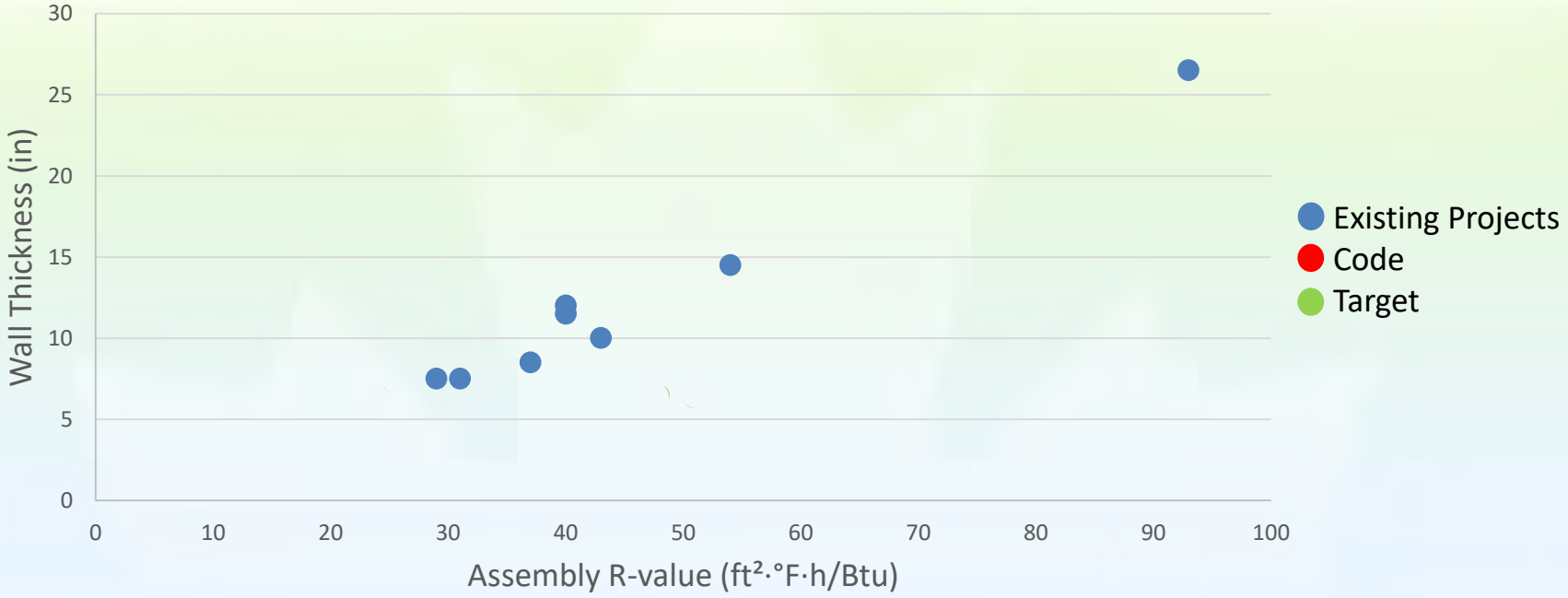
Thick walls = smaller homes

Market barrier to high performance housing

High-R, Thin Wall Project Objectives

1. Double R-value without increasing thickness
2. Use well-understood, simple assemblies and details
3. Mitigate moisture risk

R-value versus Thickness



Vacuum Insulation Panels

Vacuum contained in a metallic envelope with a porous core

Advantages

- High thermal resistivity (RSI 6.2-10.5 / 25mm or R-35 to 56 / in)
- Potential for very high RSI in a thin profile.

Issues

- Fragile and susceptible to puncture
- Finite (unknown) lifespan
- Thermal bridging along perimeter

Integration challenges

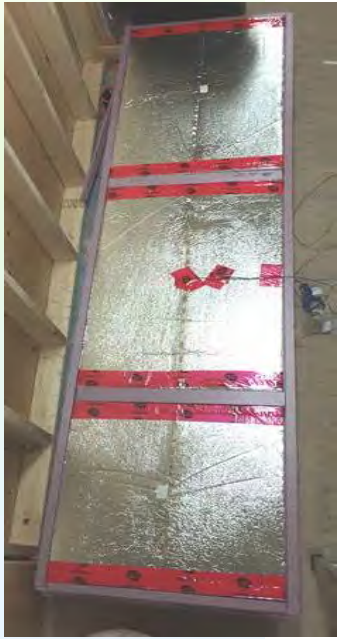
1. **Fragility:** If compromised, thermal resistance is substantially (~75%) reduced.

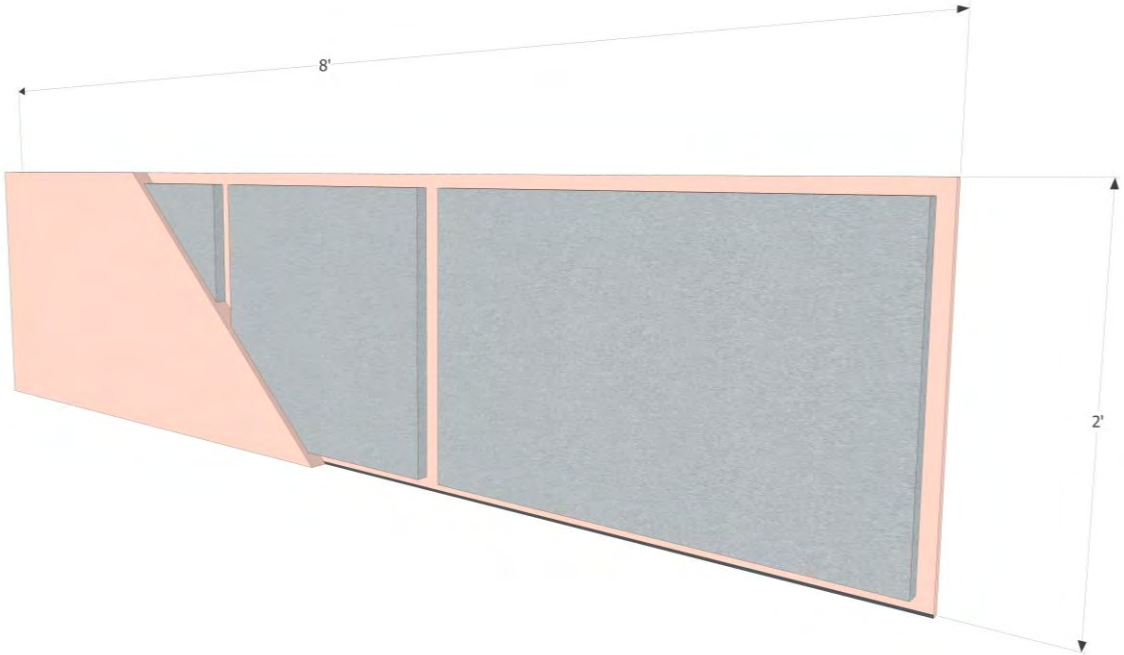
2. **Constructability:** Due to the fragility, VIPs are likely not suitable for a construction site. They need to be incorporated into a system that protects them and does not impose labour intensive installation.

3. **Thermal bridging:** Non-homogenous nature makes thermal bridging very significant.

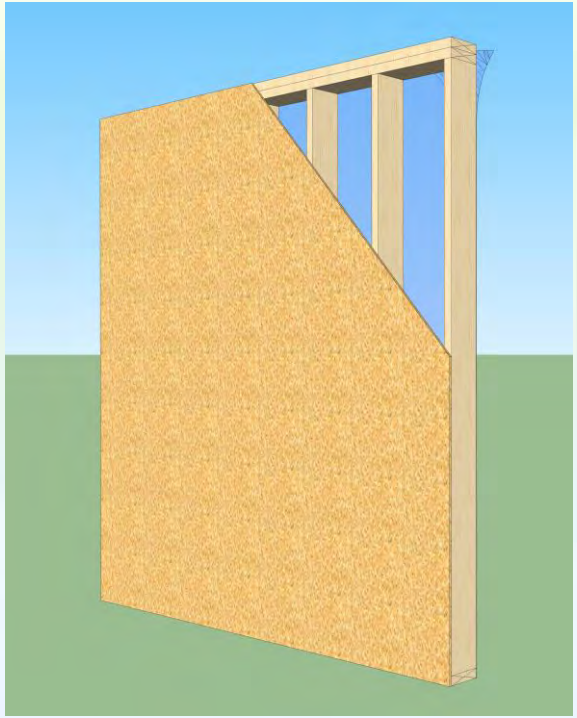
4. **Drying potential:** VIPs are vapour impermeable. Potential of trapping moisture within the wall assemblies needs to be considered in the design of the assembly.

Composite VIP Sandwich Panel





Assembly



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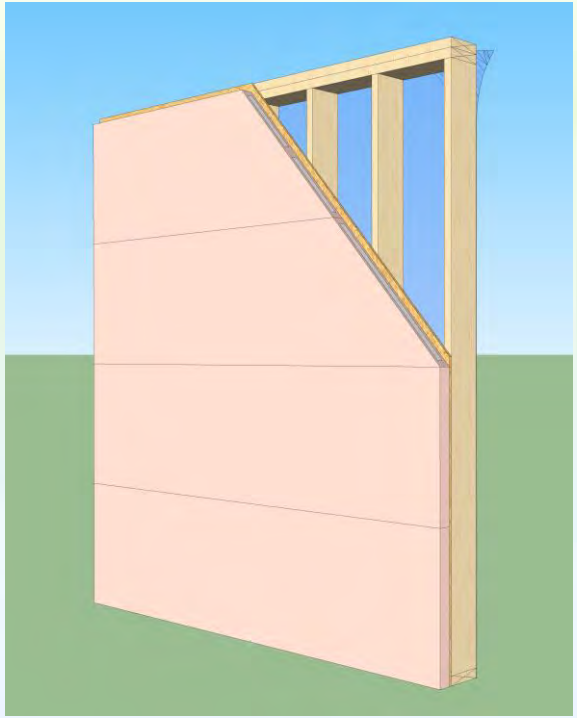

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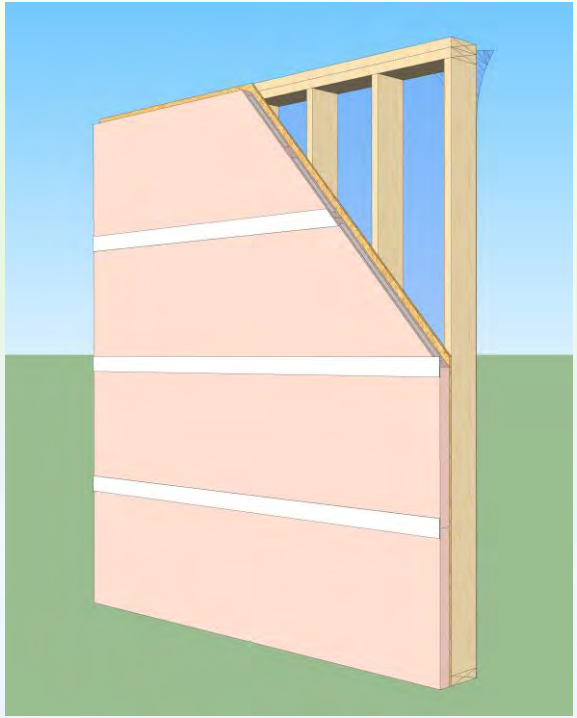
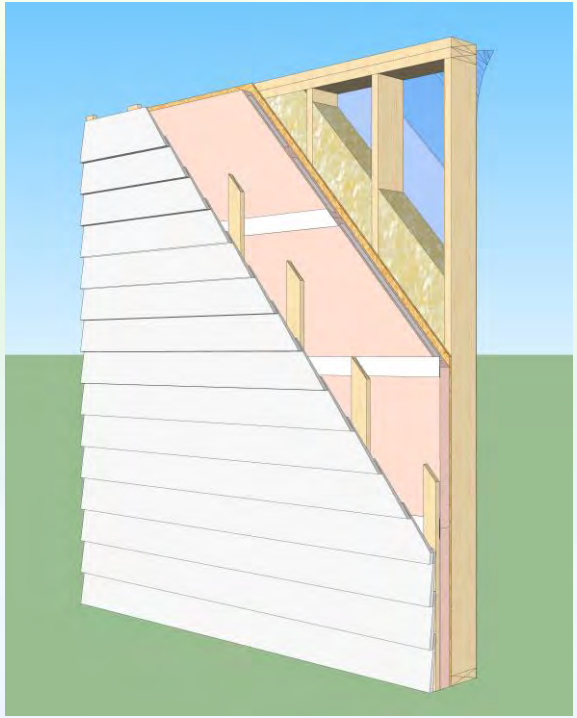


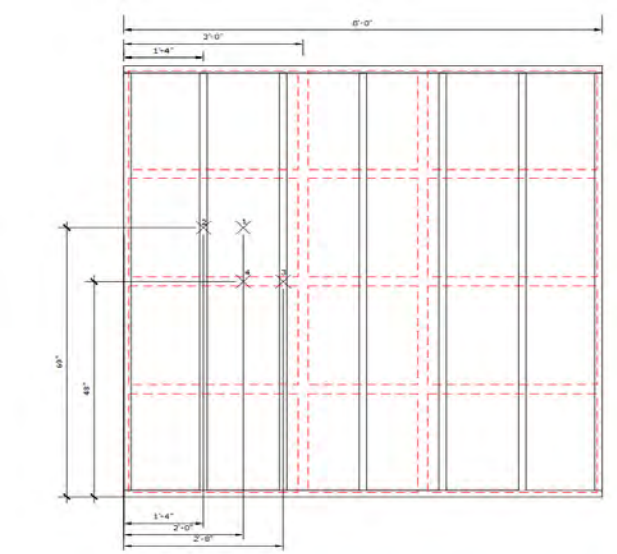
Assembly

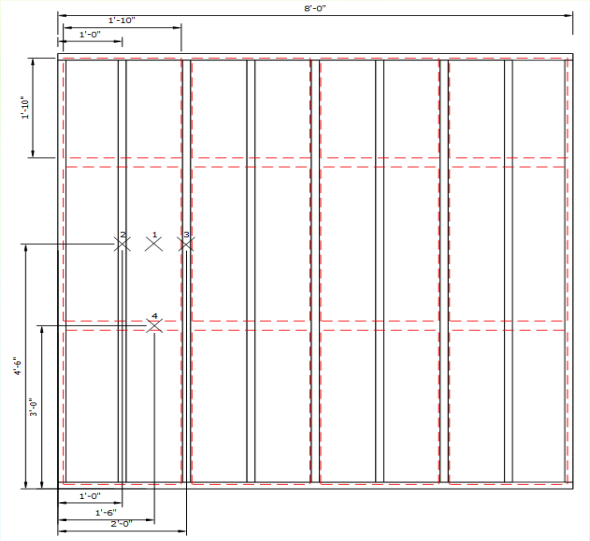


Sandwich panel thickness considerations

- Desire to use conventional fasteners for attaching insulated sheathing
- Need to ensure there is sufficient outboard thermal resistance to reduce the risk of condensation within the cavity or on sheathing

2 configurations evaluated





	Wall B (16” OC Framing)	Wall C (12” OC Framing)
Framing Factor	13.7%	16.7%
VIP Coverage	85.9%	85.9%
Aligned XPS and Stud Coverage	4.7%	9.0%

Test Facilities

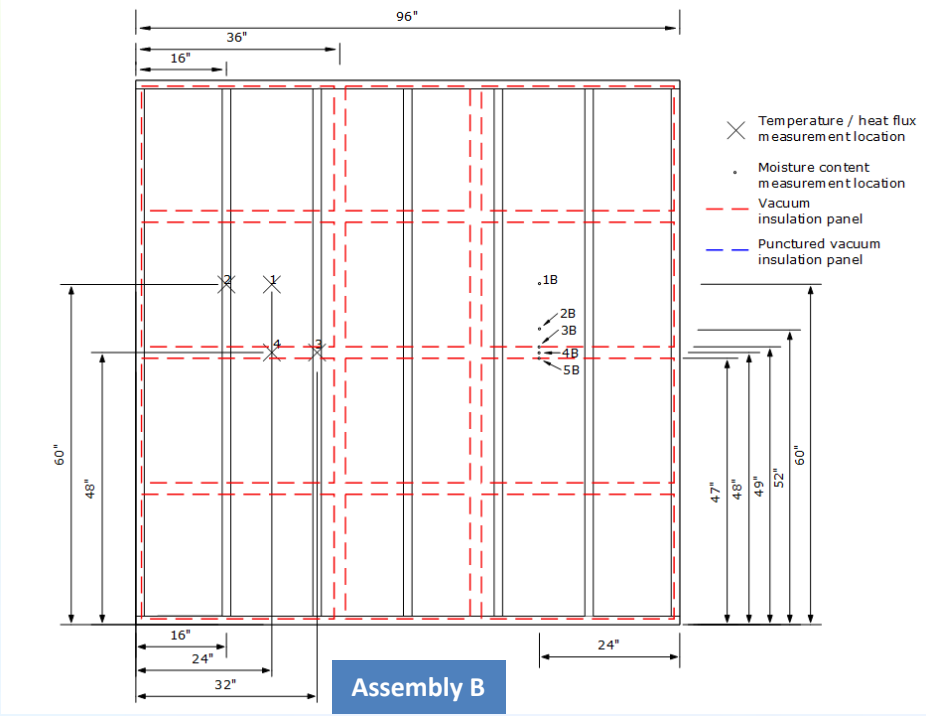
CanmetENERGY In-situ test hut for transient hygrothermal testing

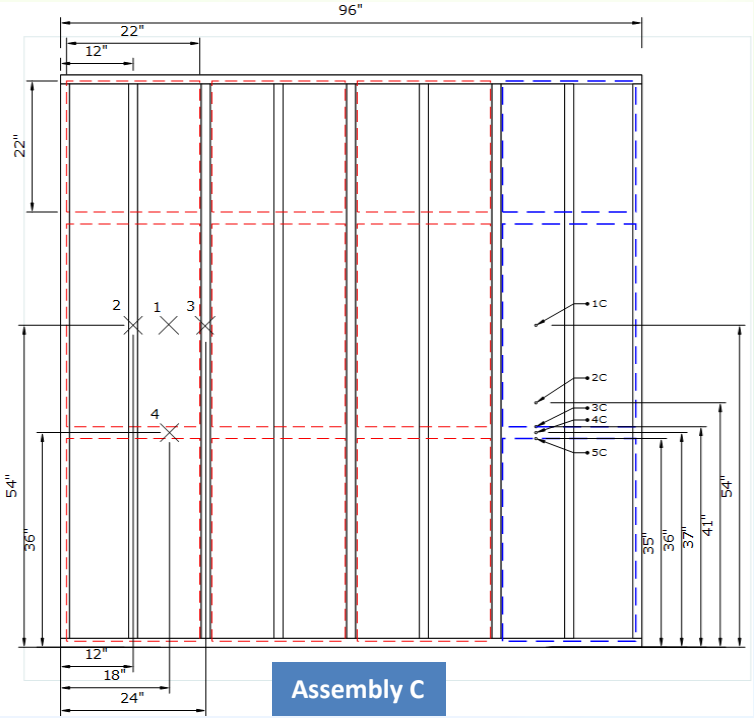
Carleton University Guarded hotbox for steady-state thermal testing

Experimental Method

- Thermal resistance evaluated in-situ at 4 unique cross sections according to ASTM C1155
- Effective thermal resistance calculated using a weighted average
- Compared to guarded hot box results

Sensor placement





Measured Thermal Resistance

Assembly	In-Situ		Guarded Hot Box	
	(K·m2/W)	(ft2·°F·hr/Btu)	(K·m2/W)	(ft2·°F·hr/Btu)
Wall A (baseline)	4.3±0.4	24.2±2	N/A	N/A
Wall B	8.61±0.6	48.9±3	8.97±0.25	50.9±1.4
Wall C	7.68±0.6	43.6±3	8.97±0.25	50.9±1.4

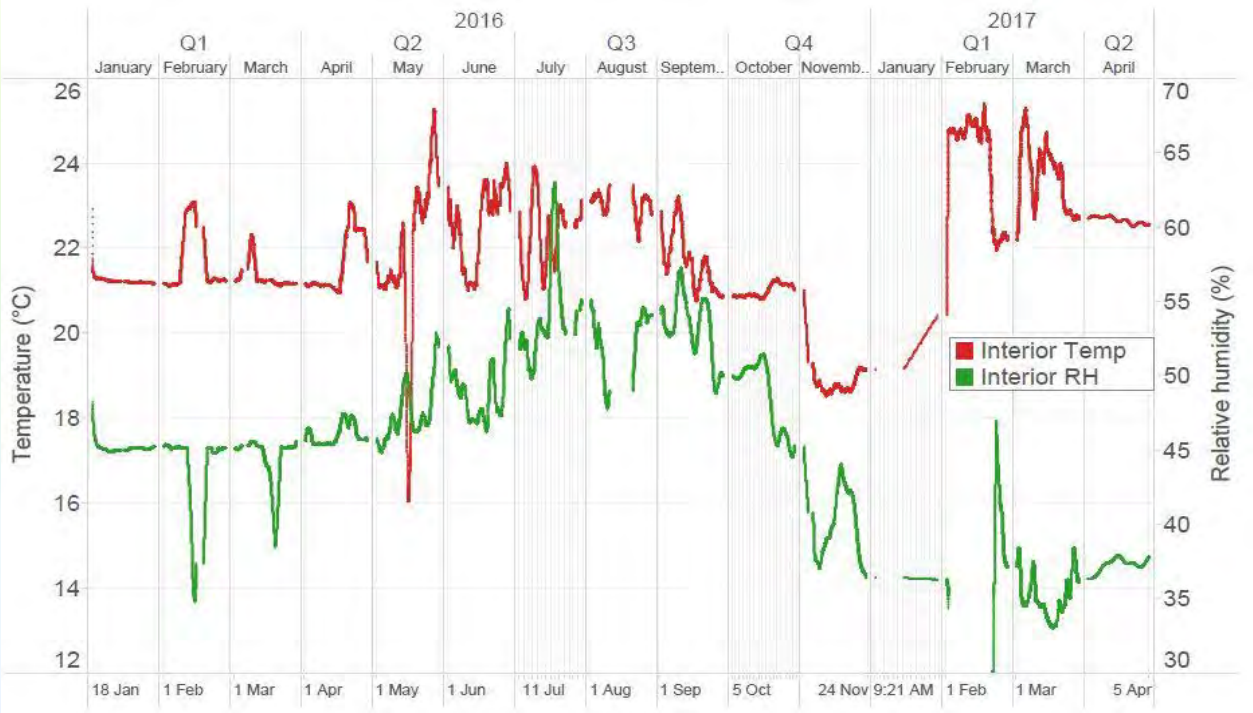
Moisture Risk Assessment Criteria

1. Does the RH and moisture content in the framing and sheathing of the experimental walls exceed those of the baseline assembly?
2. To minimize the potential for mold growth:
   a. 30-day running average surface RH should be < 80%
   b. 7-day running average surface RH should be < 98%
   c. 24-h running average surface RH should be < 100% .
3. To avoid rot, moisture content of wood should remain <28%

ASHRAE 160-2009

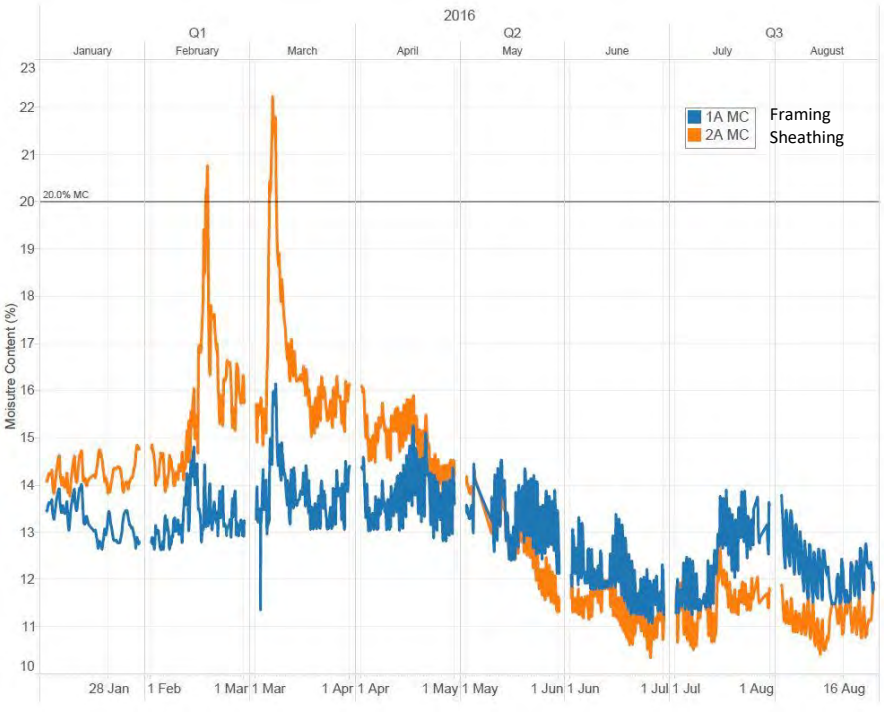
Interior Conditions

- 21°C temperature, 45% relative humidity during the 2016 winter;
- 22°C temperature, uncontrolled humidity (allowed to float) during the summer;
- 22°C temperature, 35% relative humidity during the 2017 winter.

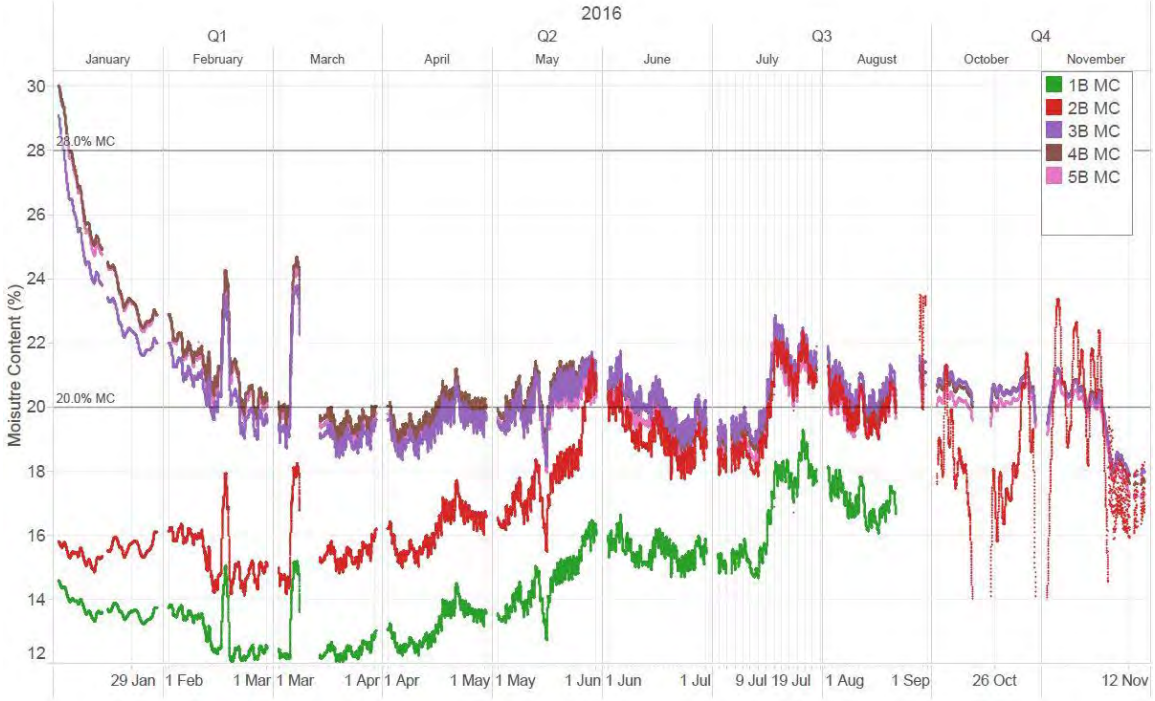


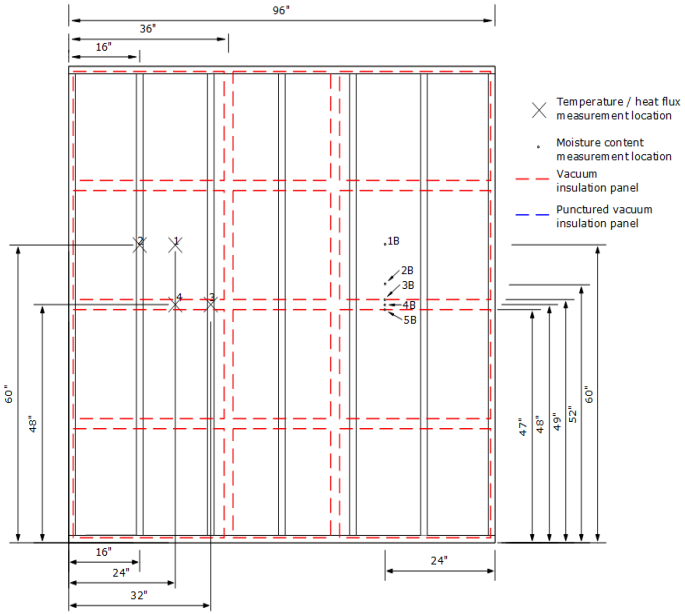
1-day running average of Interior Temperature and Relative Humidity

Moisture content in Wall A (baseline)

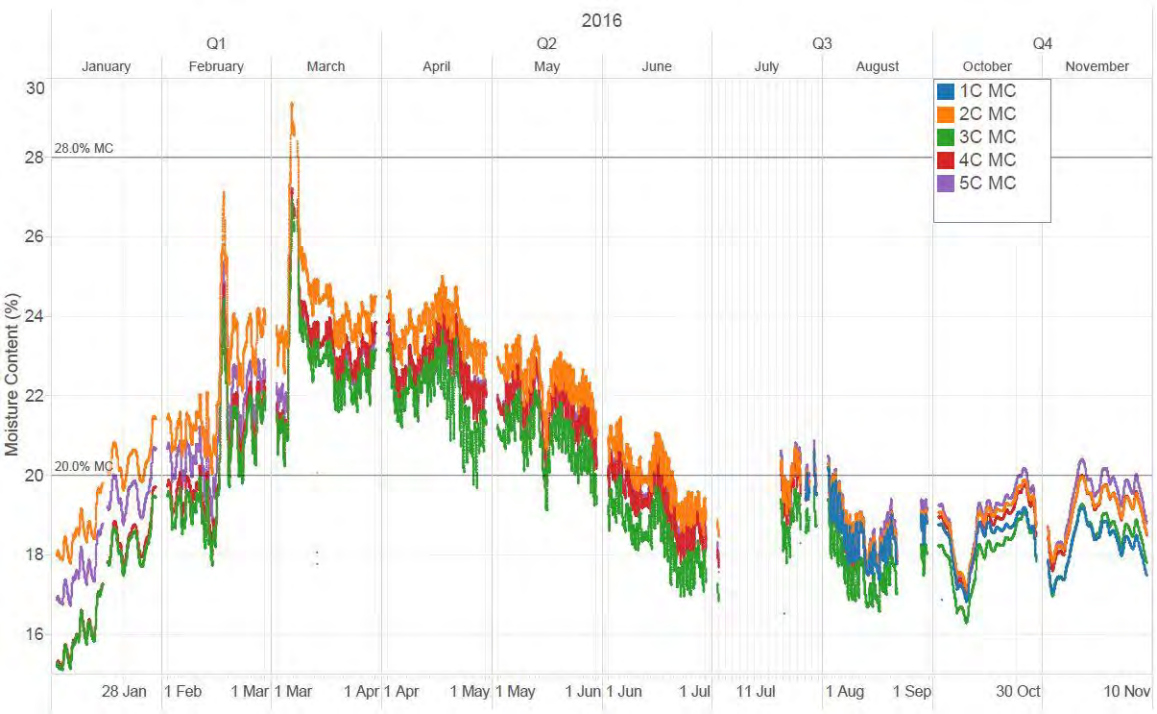


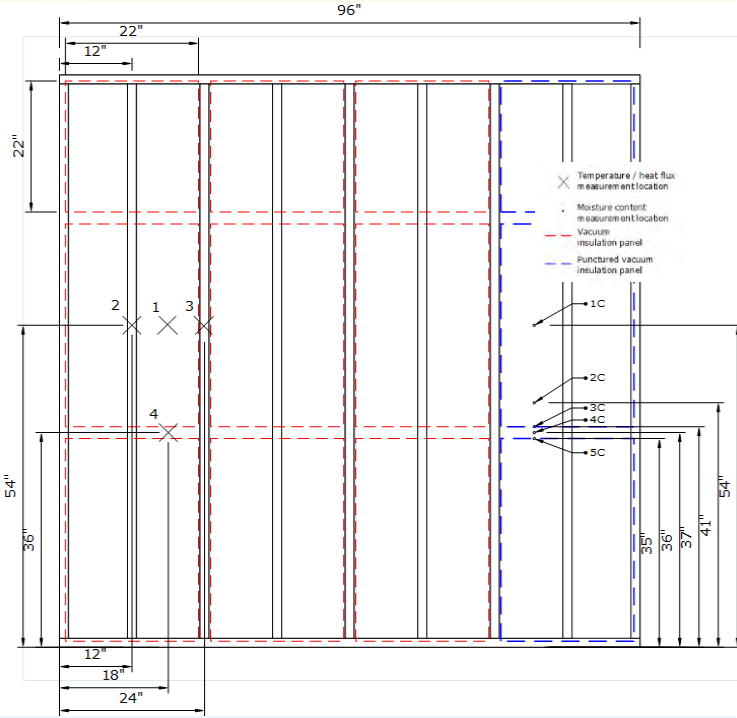
Moisture content of Wall B sheathing behind intact VIPs



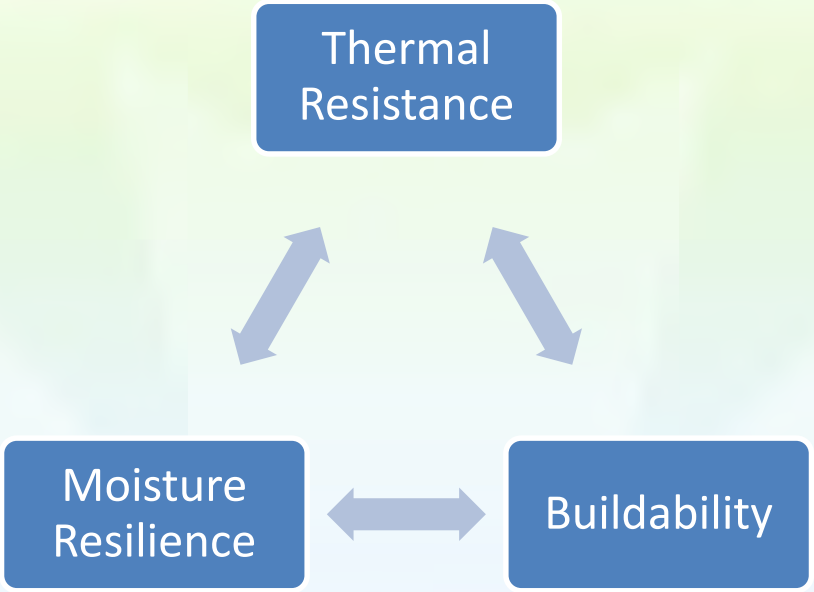


Moisture content of Wall C sheathing behind compromised VIPs





Balancing design priorities



Conclusions: Project Outcomes vs Objectives

1. Double R-value without increasing thickness
   - *R-values > RSI 8 (R-45) achieved in 150 mm (6”) assembly*
2. Use well-understood, simple assemblies and details
   - *Even protected with XPS, VIPs are not suited for field installation. Best suited for factory environment*
   - *Limitations in VIP sizes limits design flexibility*
   - *Perhaps best suited for modular construction*
3. Mitigate moisture risk
   - *Elevated levels of moisture content (particularly behind failed VIPs) relative to baseline assembly*
   - *Risk reduced by increasing outboard R-value, or mechanically controlling interior humidity*
   - *Longer term testing necessary*

Next Steps

- Continued monitoring
- Controlled wetting events
- Enhancing designs to reduce risk

Thanks

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