State of the art review of unvented sloped wood- framed roofs

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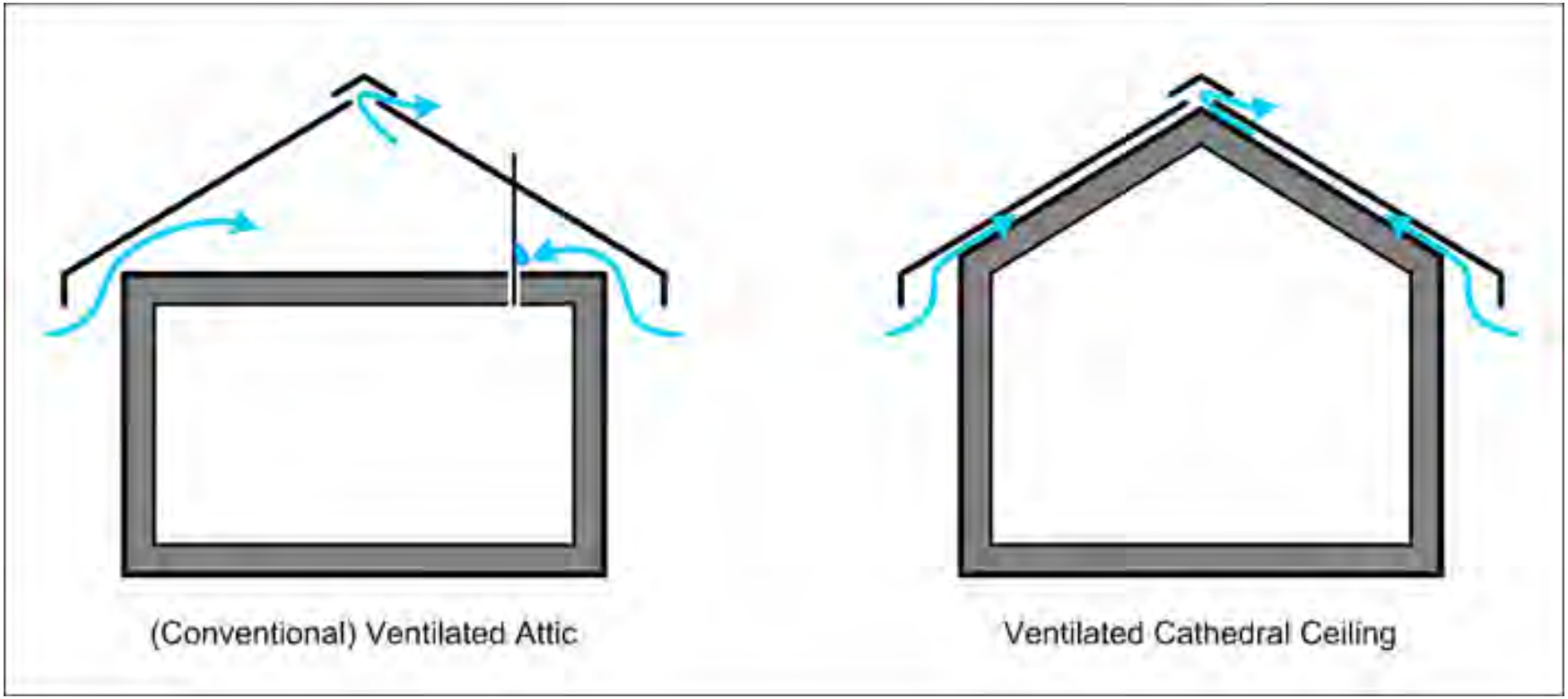
Outline

- *Driving Building Science to the Next Level*
  - Using Science to make Building Design decisions?
  - Yes, but also need to incorporate experience
- This paper
  - Literature review / meta-analysis
  - Research + Field Experience
- This presentation
  - Some background, some highlights

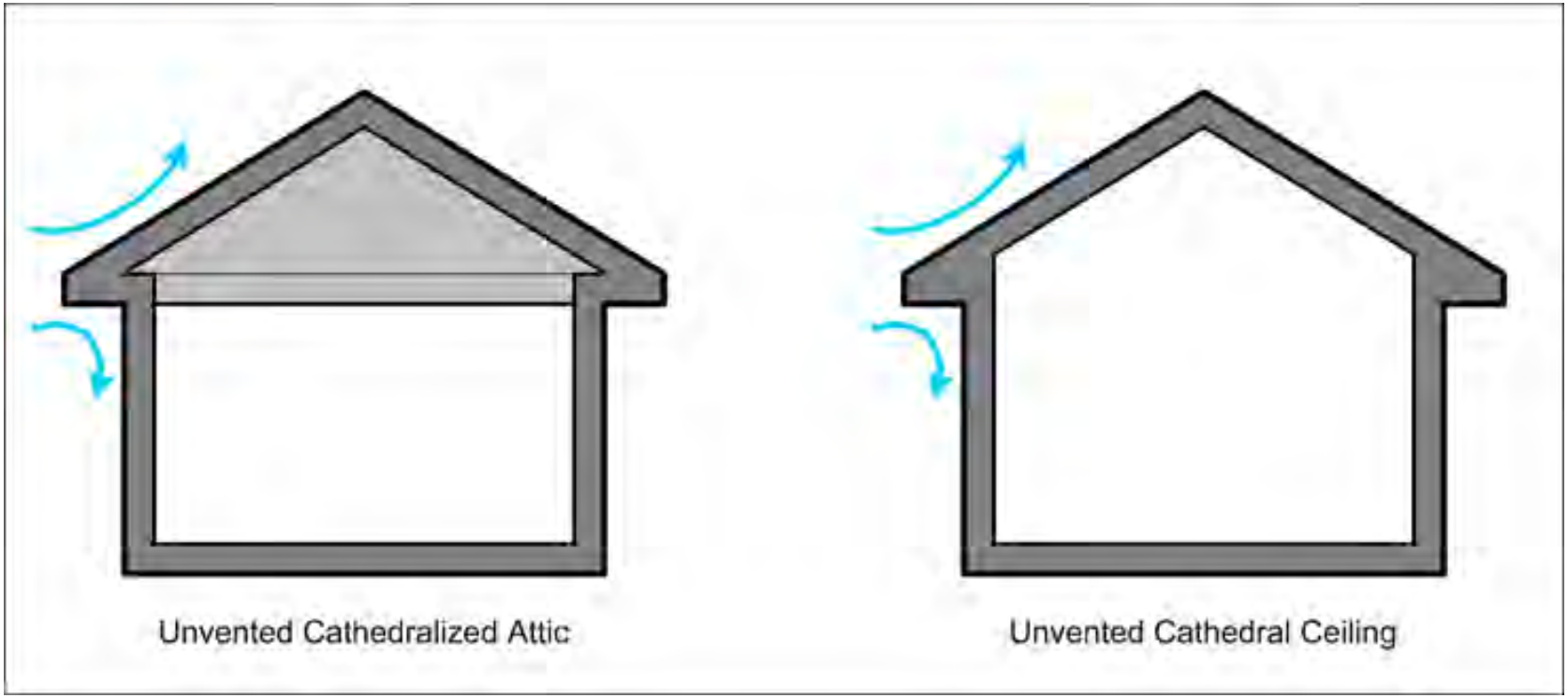
Pitched Roof Types - Ventilated

- **Vented Attic**
  - Air, vapor and thermal control at ceiling
  - Rain control at roof
- **Cathedral Ceiling**
  - Air, vapor, thermal and rain control at roof

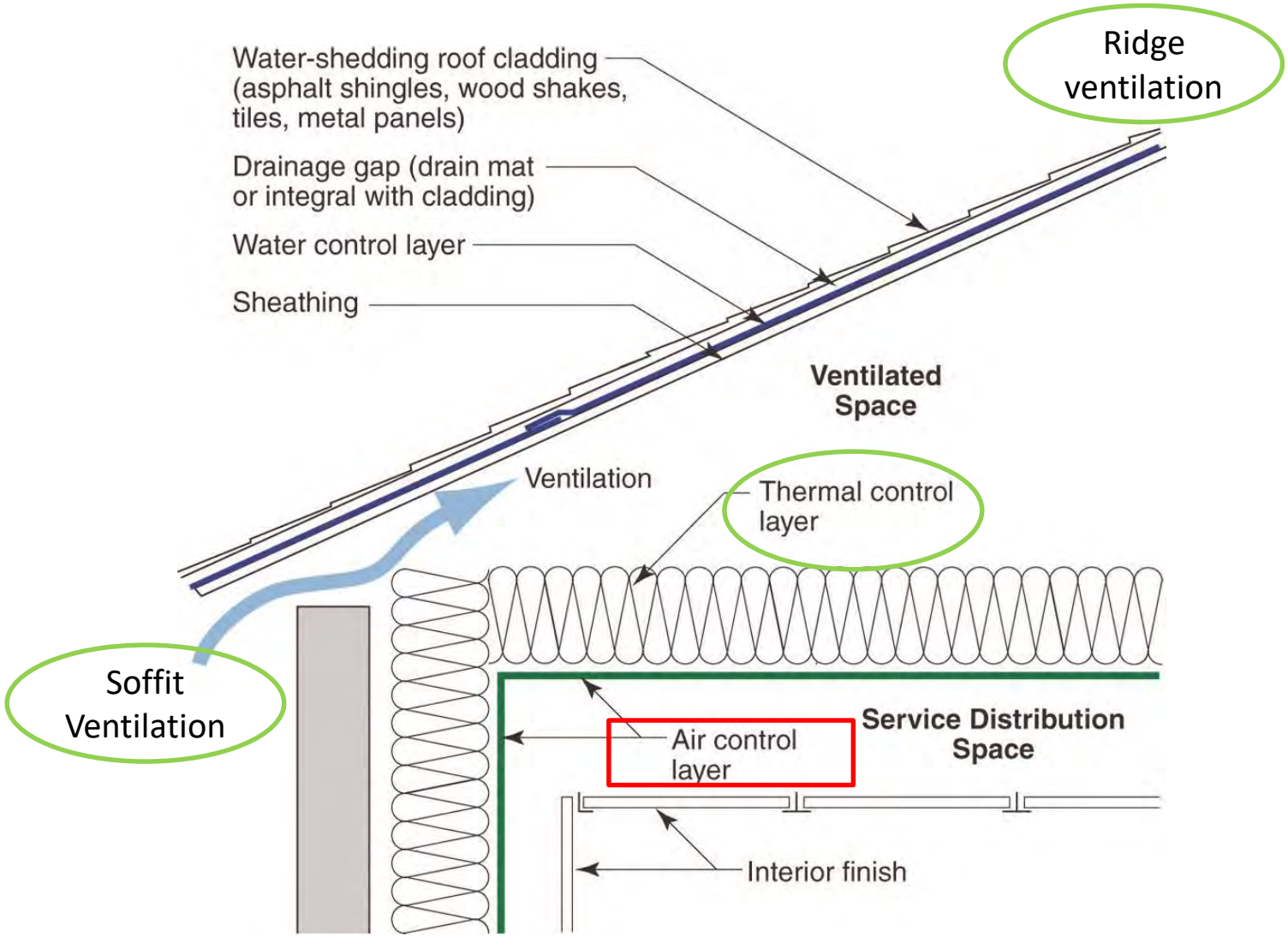


Pitched Roof Types

- **Unvented Cathedralized Attic**
  - More useable space as retrofit
  - Space for mechanical equipment
- **Unvented Cathedral**



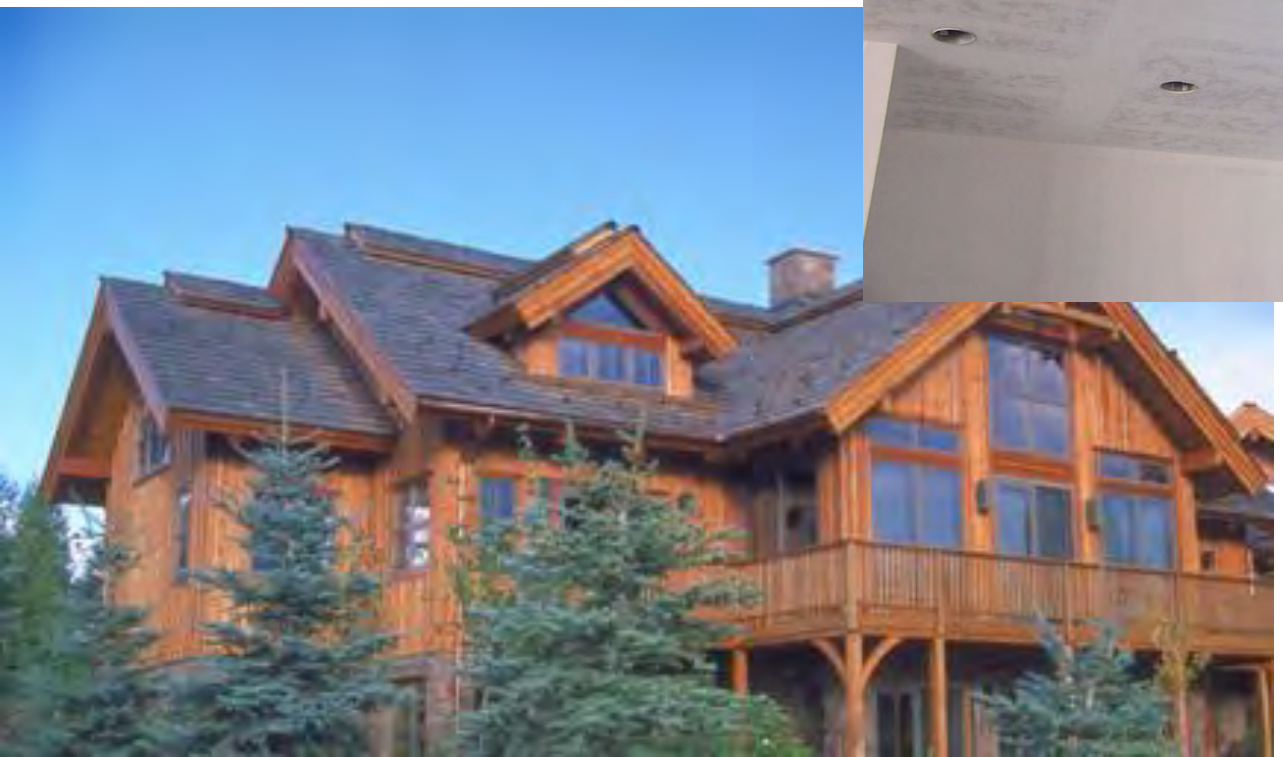
Ideal Ventilated Attic Construction



Nice venting
Clean roofing ply

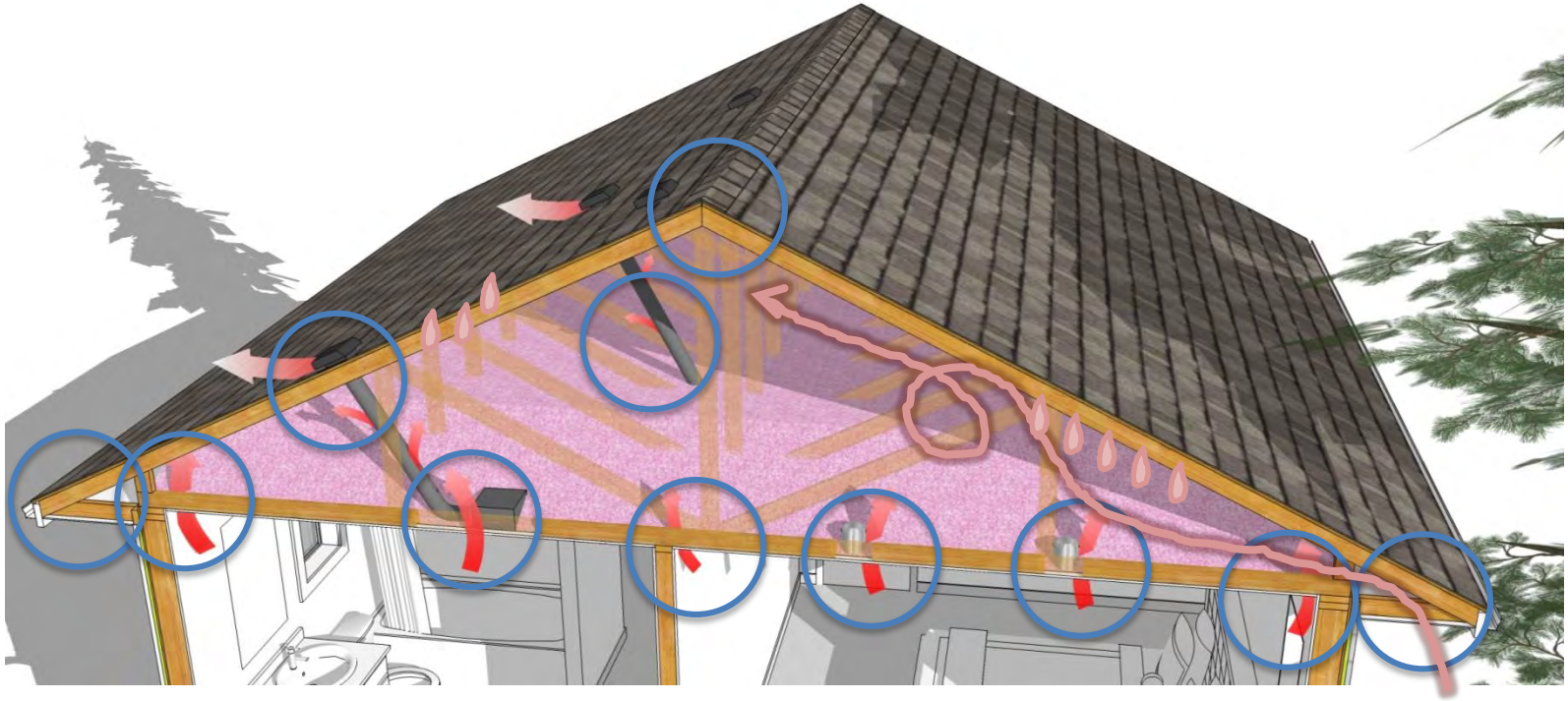
Reality of Ventilated Attics

- Venting **complexity** & **air leakage** through ceiling

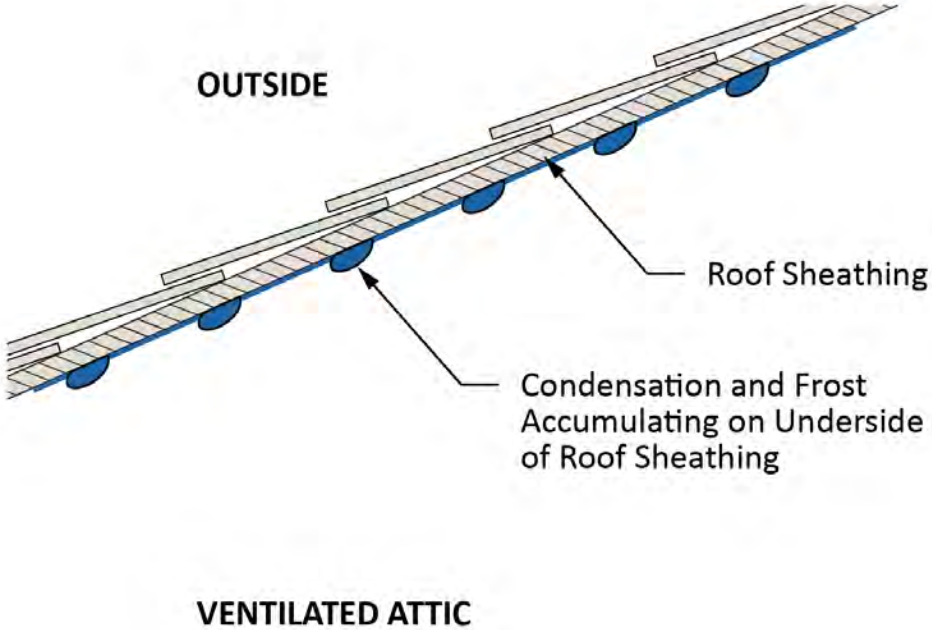


Air leakage condensation: decades of problems

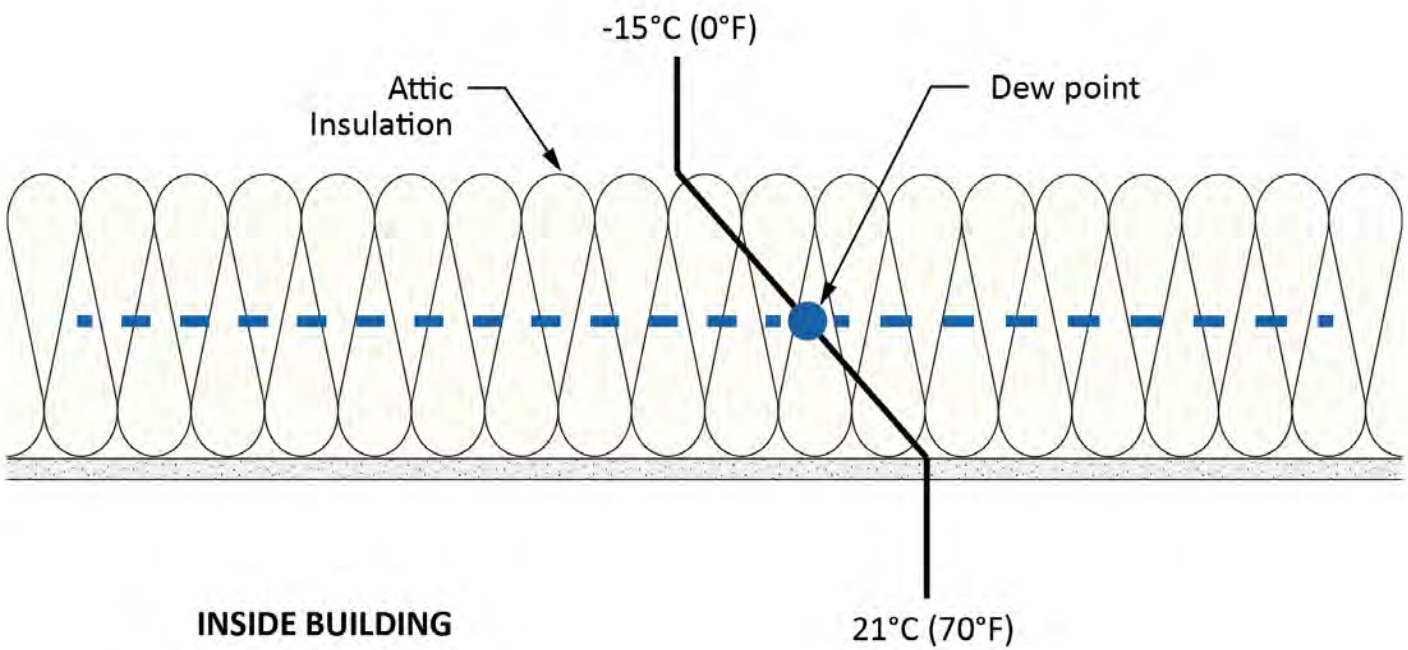
Moisture Sources



- **Air leakage**
  - ceiling penetrations, top plate penetrations
  - Exhaust duct leaks & discharge location (roof, soffit, or wall)
- Inadequate venting provisions
- Outdoor moisture: night sky condensation on underside of sheathing… caused by ventilating attic
- Wetting through shingles/roofing? (tipping the moisture balance)

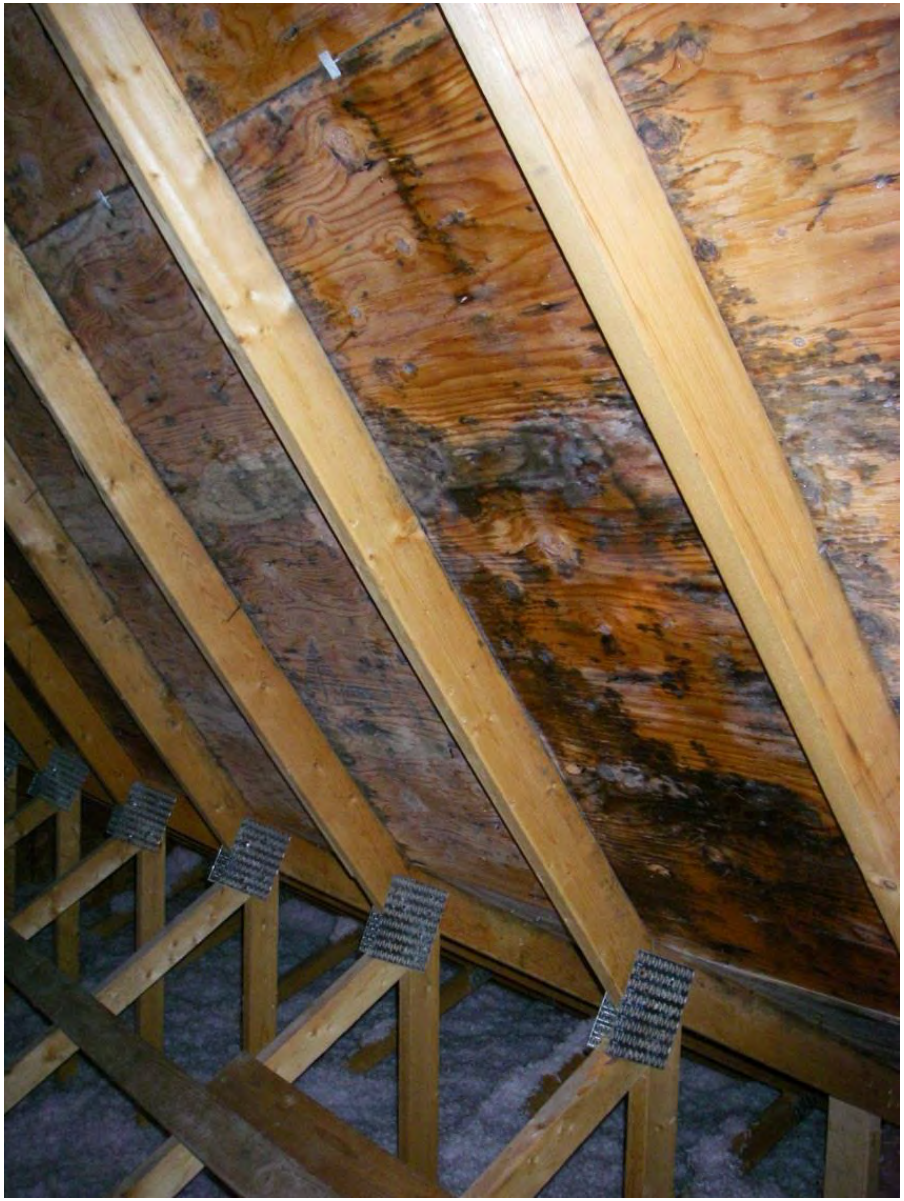


"Condensation occurs on the first solid upstream facing surface downstream of the dewpoint being exceeded"



Nice venting…
Moldy roofing ply

Ventilation Cant solve excess air leakage or high interior RH



Research

- Moisture in ventilated attics has long been researched
- Jordan, C.A., E.C. Peck, F.A. Strange, and L.V. Teesdale. **1948**. *Attic condensation in tightly built houses*. Housing and Home Finance Agency Technical Bulletin No 6, pp. 29-46.

Vented Attics – Previous Work

- Rose and TenWolde (1999, 2002)
- "We conclude that while attic ventilation can be beneficial in some circumstances and climates**, it should not be viewed as the principal strategy to eliminate moisture and other problems in the attic and roof**. Rather, attic ventilation should be part of a broader range of control strategies."
- "In summary, for each of the most commonly cited claims of benefits offered by attic ventilation (reducing moisture problems, minimizing ice dams, ensuring shingle service life, and reducing cooling load), **other strategies have been shown to have a stronger and more direct influence.** Consequently, the focus of regulation should be shifted away from attic ventilation."

Vented Attics – Previous Work

- Potential Issues in colder humid coastal climates
- Forest and Walker, 1993
  - High attic ventilation rates resulted in higher sheathing moisture content – measurment & simulations in humid climates
- Roppel et al. 2013
  - Characterized attics, measured, monitored.
  - venting area and an airtight ceiling alone is not enough to control moisture, to limit mold growth, in insulated attics of wood-framed sloped roofs in marine climates, similar to Vancouver's climatic zone.

Unvented Roofs

- Can we safely building *unvented* roofs?

- **No doubt**, in either science or practise
  - Not all codes have caught up (e.g., NBCC)
- **However**, must have
  - Exceptional air tightness near inside
  - Low built-in moisture
  - This limits design choices

Commercial Unvented Roofs

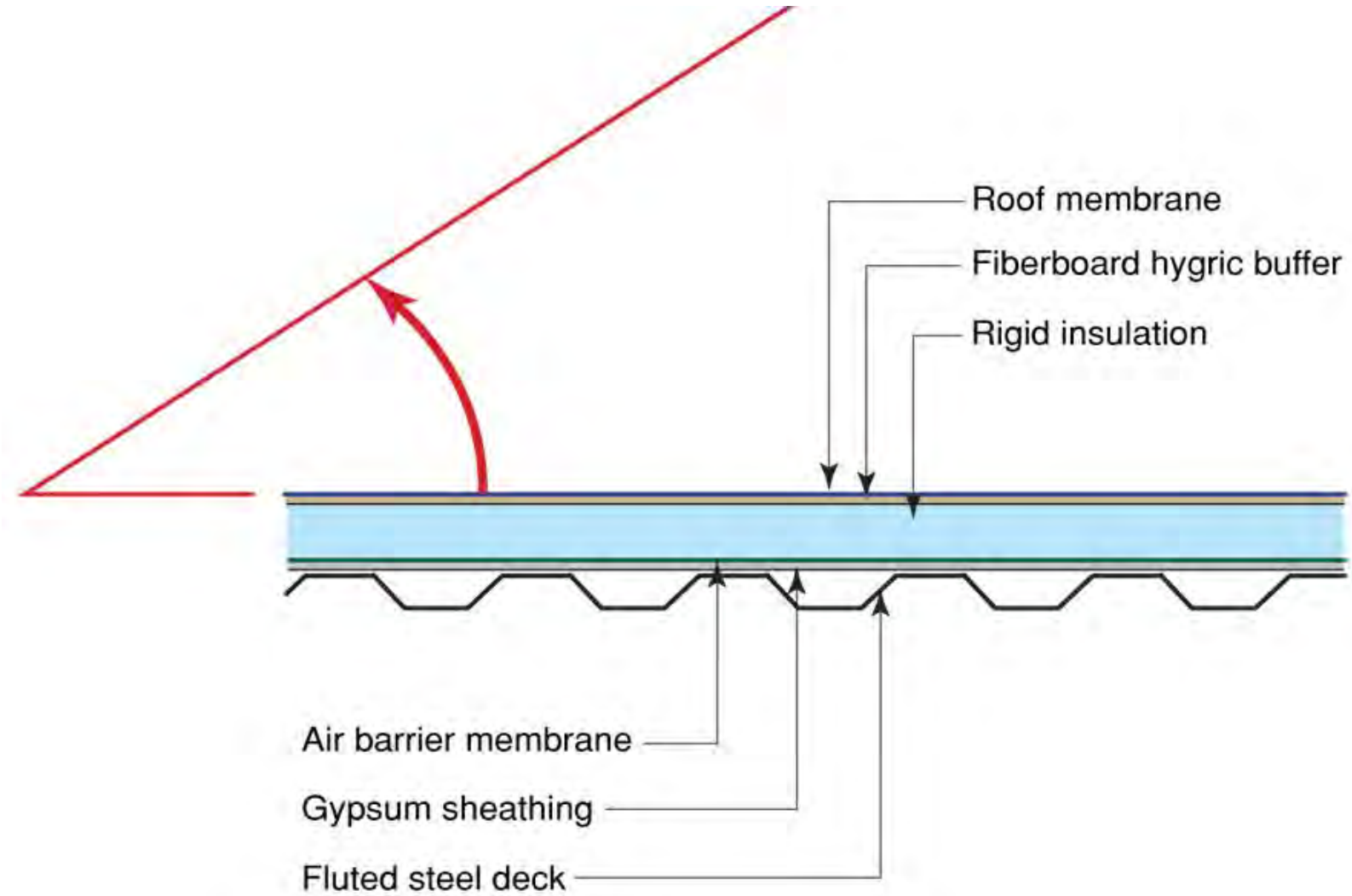
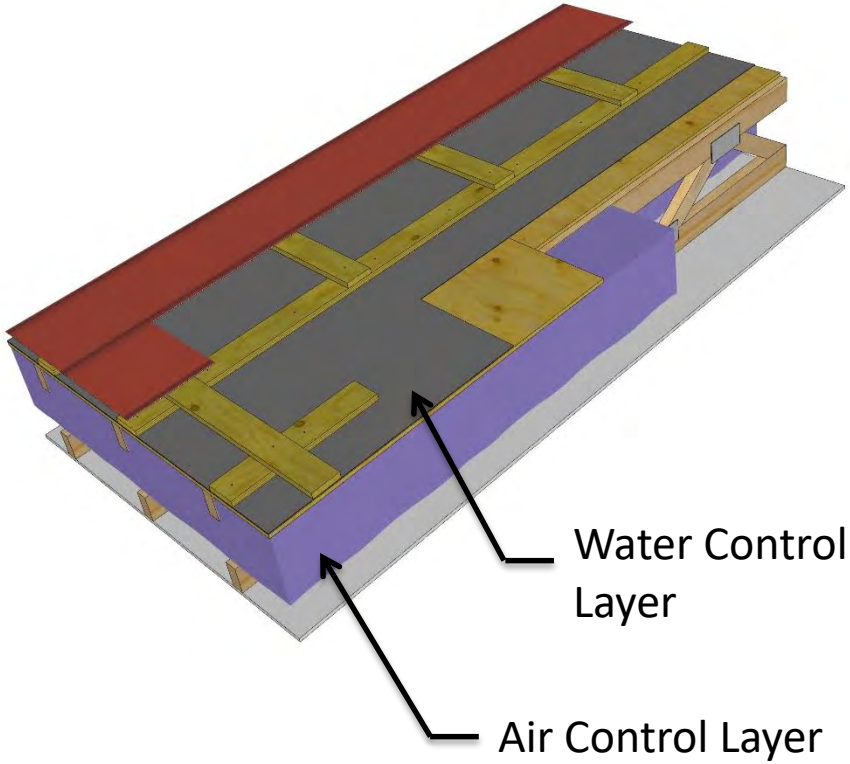
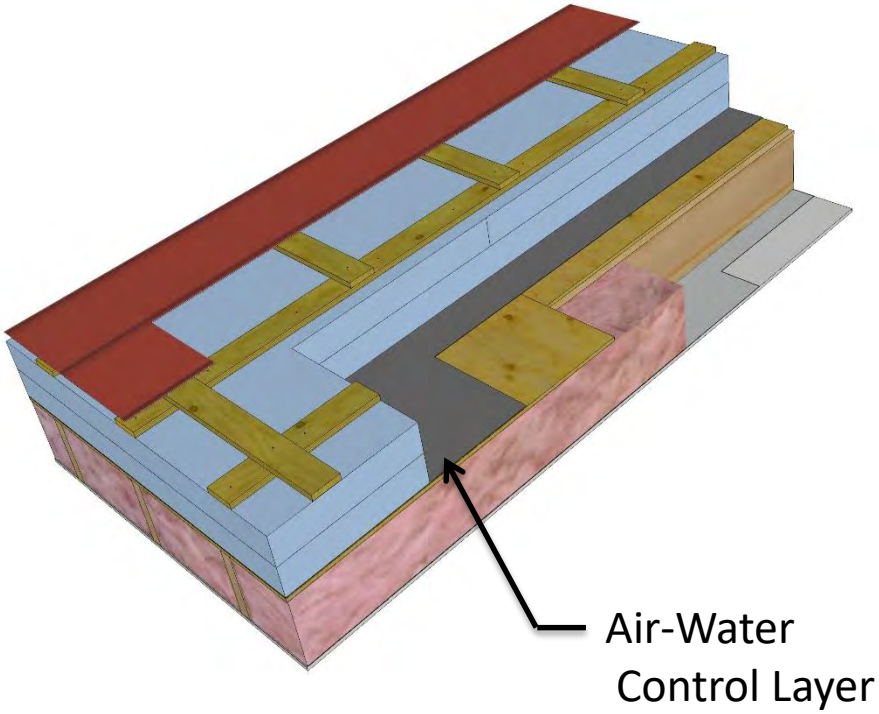


Image credit: Building Science Corporation

Unvented Wood-frame solutions

- Unvented Hot Roof (Sprayfoam applied to underside)
- Exterior Insulated & hybrid approaches





Sloped Unvented Wood Roofs

Control Layers
Exterior of Structure
- Ideal assembly

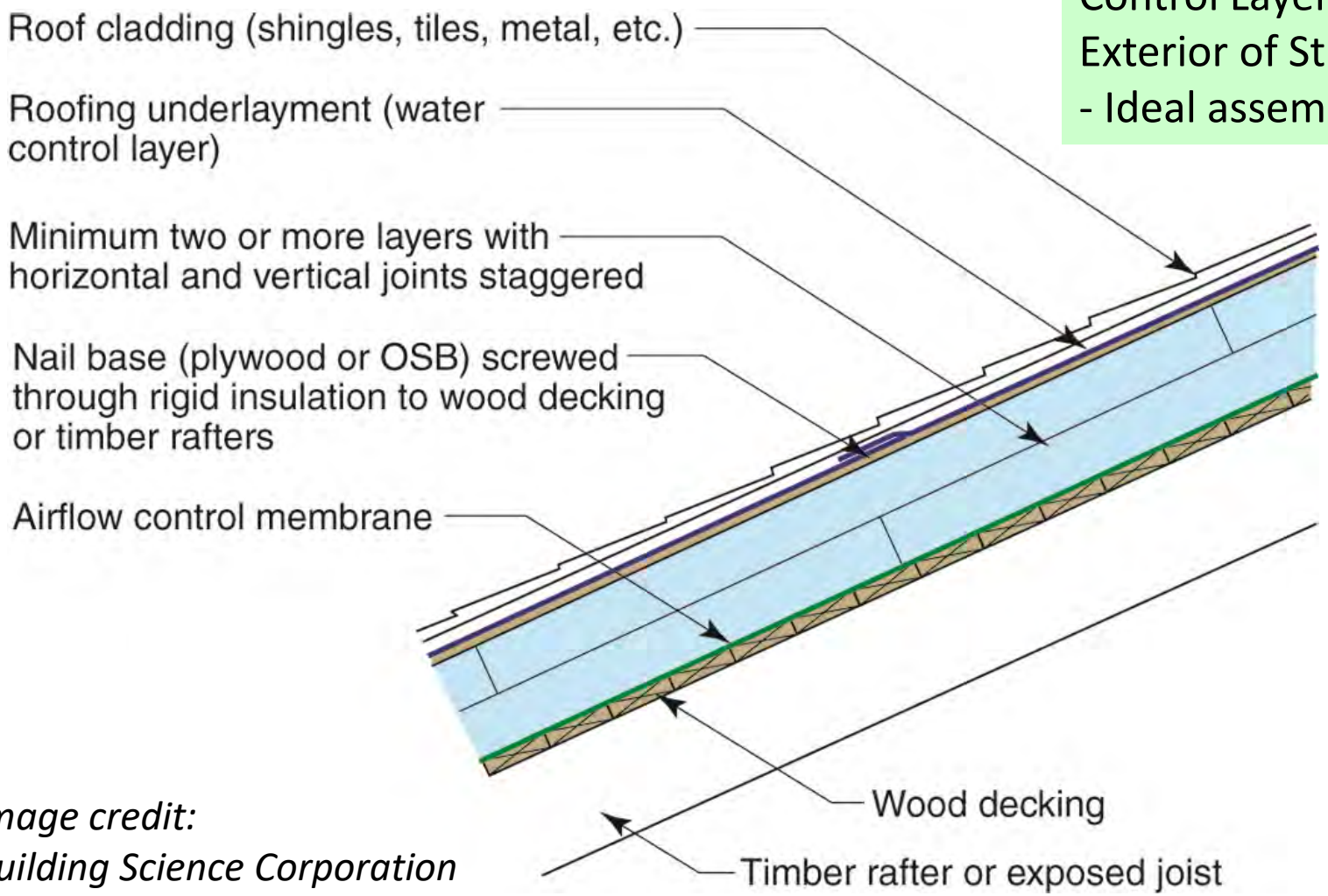
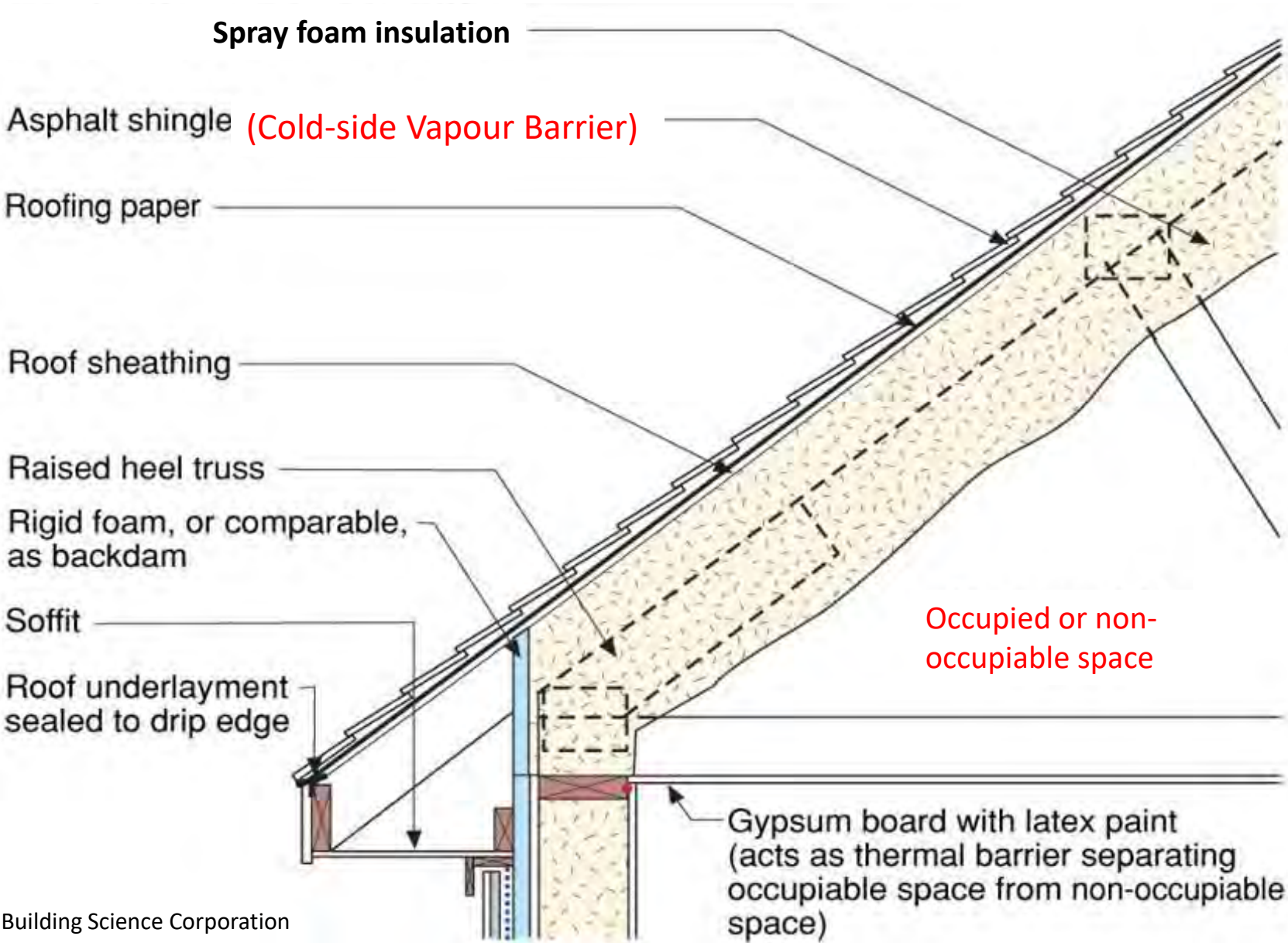


Image credit:
Building Science Corporation

Unvented Wood Frame



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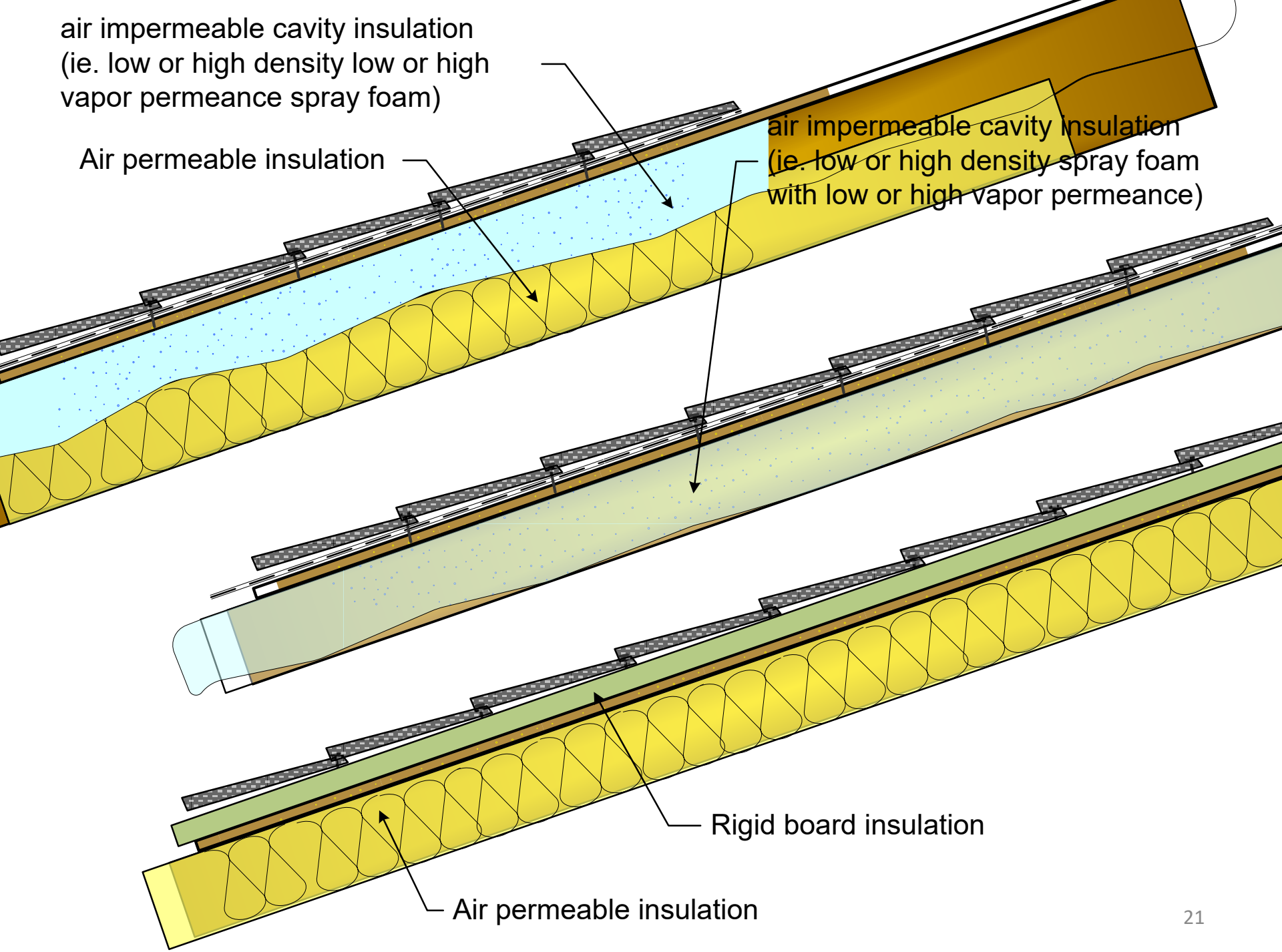

air impermeable cavity insulation
(ie. low or high density low or high
vapor permeance spray foam)
Air permeable insulation
air impermeable cavity insulation
(ie. low or high density spray foam
with low or high vapor permeance)
Rigid board insulation
Air permeable insulation

Can we build unvented roofs?

- Canadian Part 9 doesn't allow this
  - Need to get engineers letter, etc.
- American IRC/IBC allows with specific limits
  - Significant research and experience to support this
- Canadian Part 4 (professional) = most common roof assembly

Canadian Code : NBC Part 9

- Residential Section 9 (9.19.1)
  - Requires venting of all roofs unless an engineer signs off
  - Requires a vapour control layer not greater than 60 ng/Pa·s·m^2. (1 US perm)
- Unvented residential roof assemblies not allowed by code…. Clause 9.19

Part 9 NBC of Canada

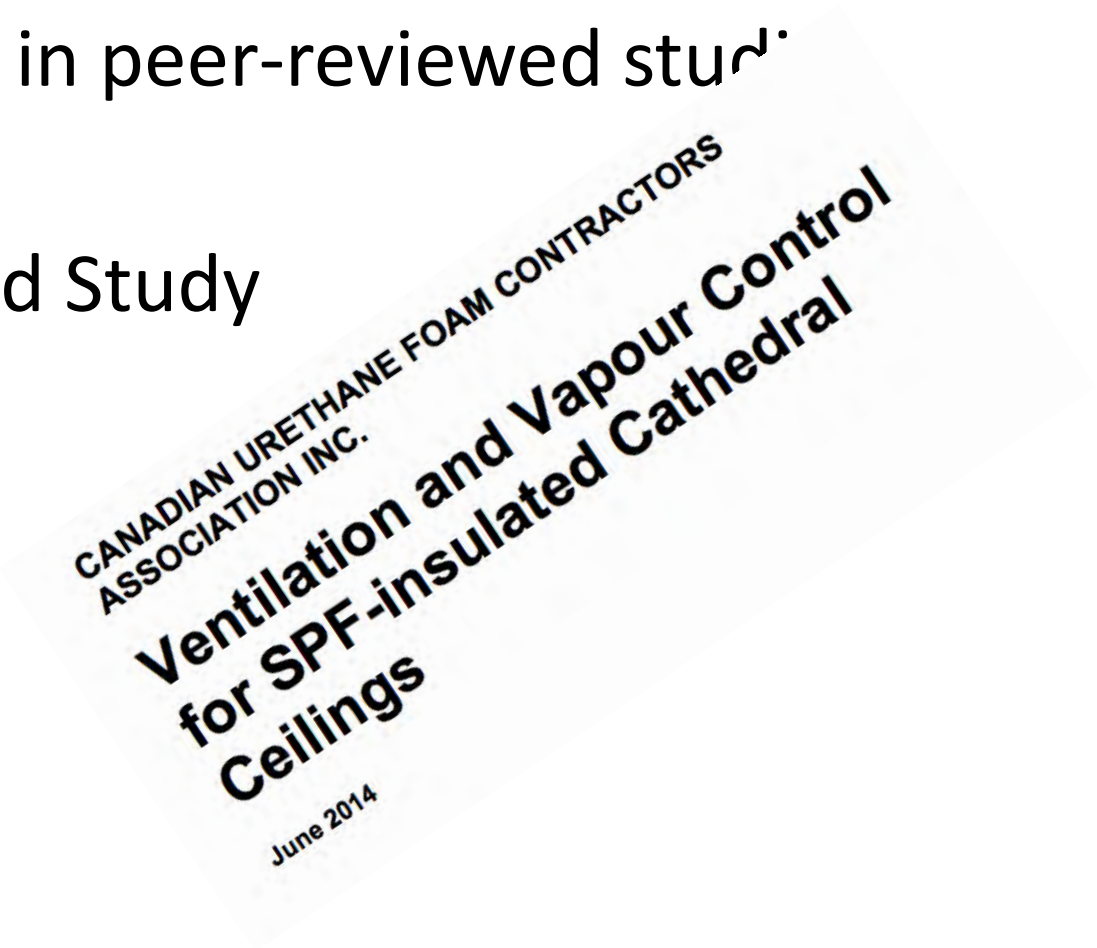
- “Except where it can be shown to be unnecessary, where insulation is installed between a ceiling and the underside of the roof sheathing, a space shall be provided between the insulation and the sheathing, and vents shall be installed to permit the transfer of moisture from the space to the exterior” **9.19.1.1**
- Sensible rule for pitched wood-frame roofs, without a practical solution for airtight insulation
- Spray polyurethane foam has been successful because it is a practical solution to airtight insulation

U.S. Code: IRC R806.5

- Unvented cathedralized attics and unvented cathedral ceilings allowed
- No additional vapor control needed in Zones 1-4 (just control of air leakage)
- Insulation needs to be Class II vapor control (0.1 to 1.0 perms) or have Class II in direct contact
  - Zones 5 and higher need vapour control
  - E.g., virtually all of Canada needs vapor control

Field Research

- Numerous US and Canada studies
- Sprayfoam papers in peer-reviewed studi from 2005 (Rudd)
- U of Waterloo Field Study



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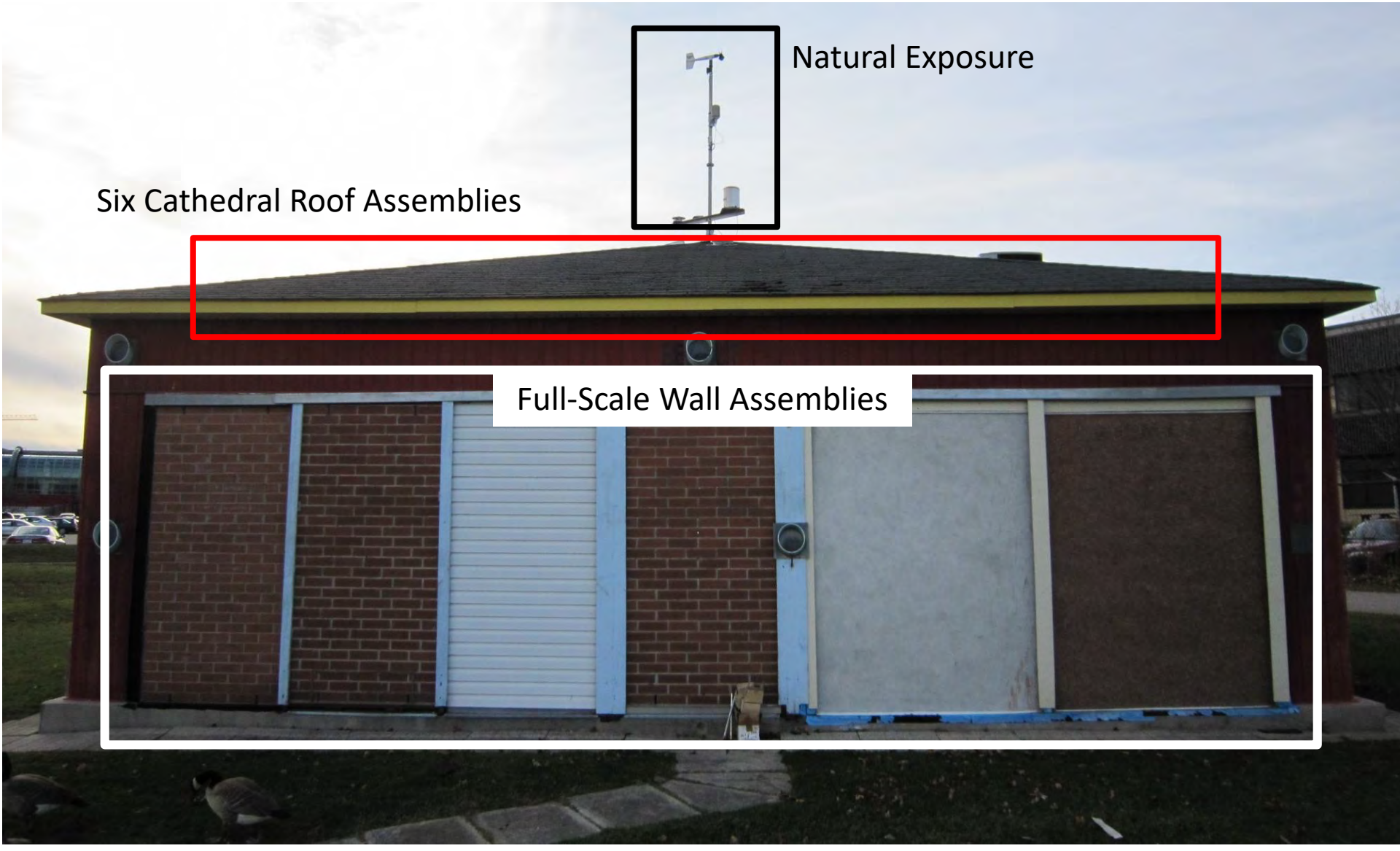
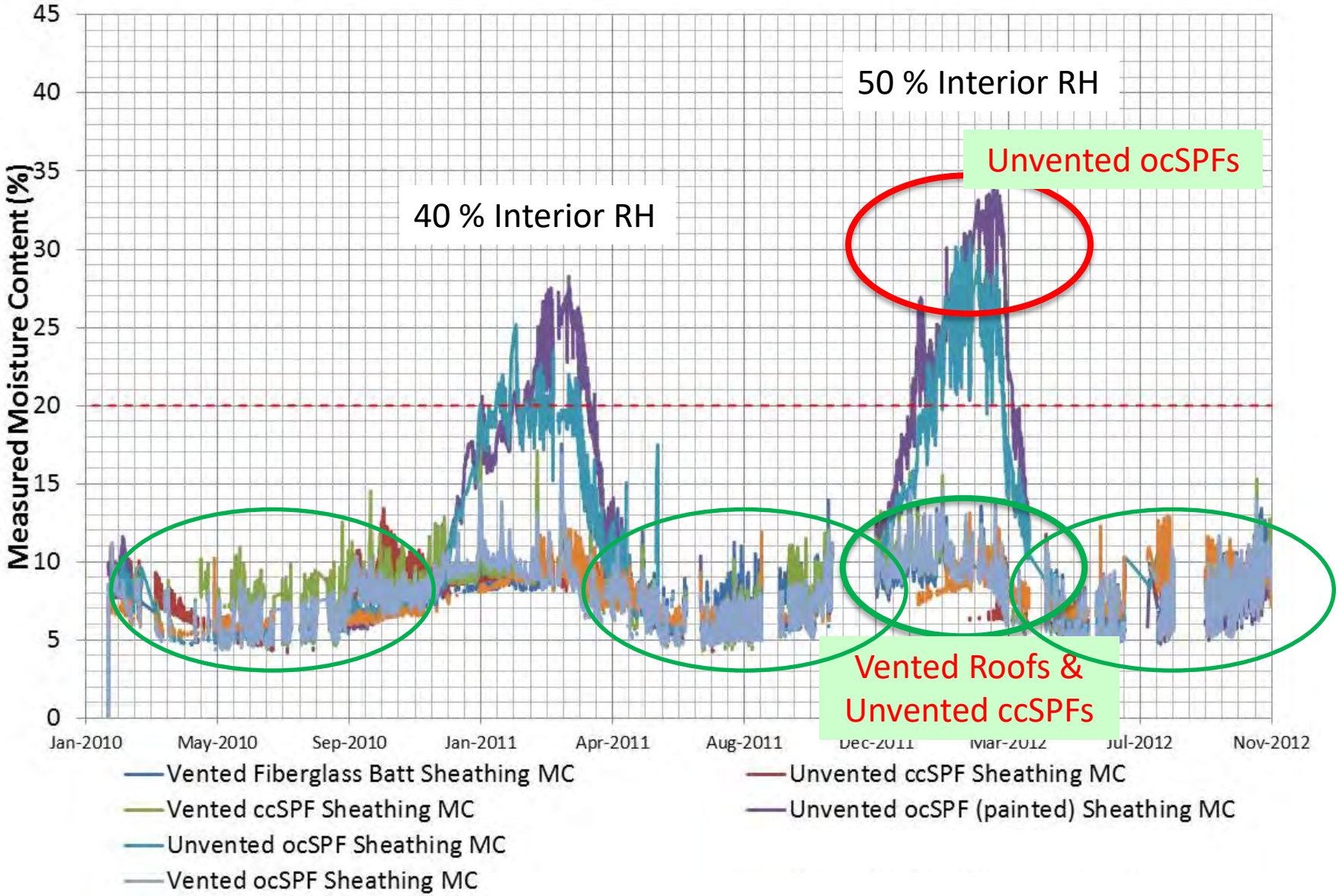
Building Engineering Group (BEG)

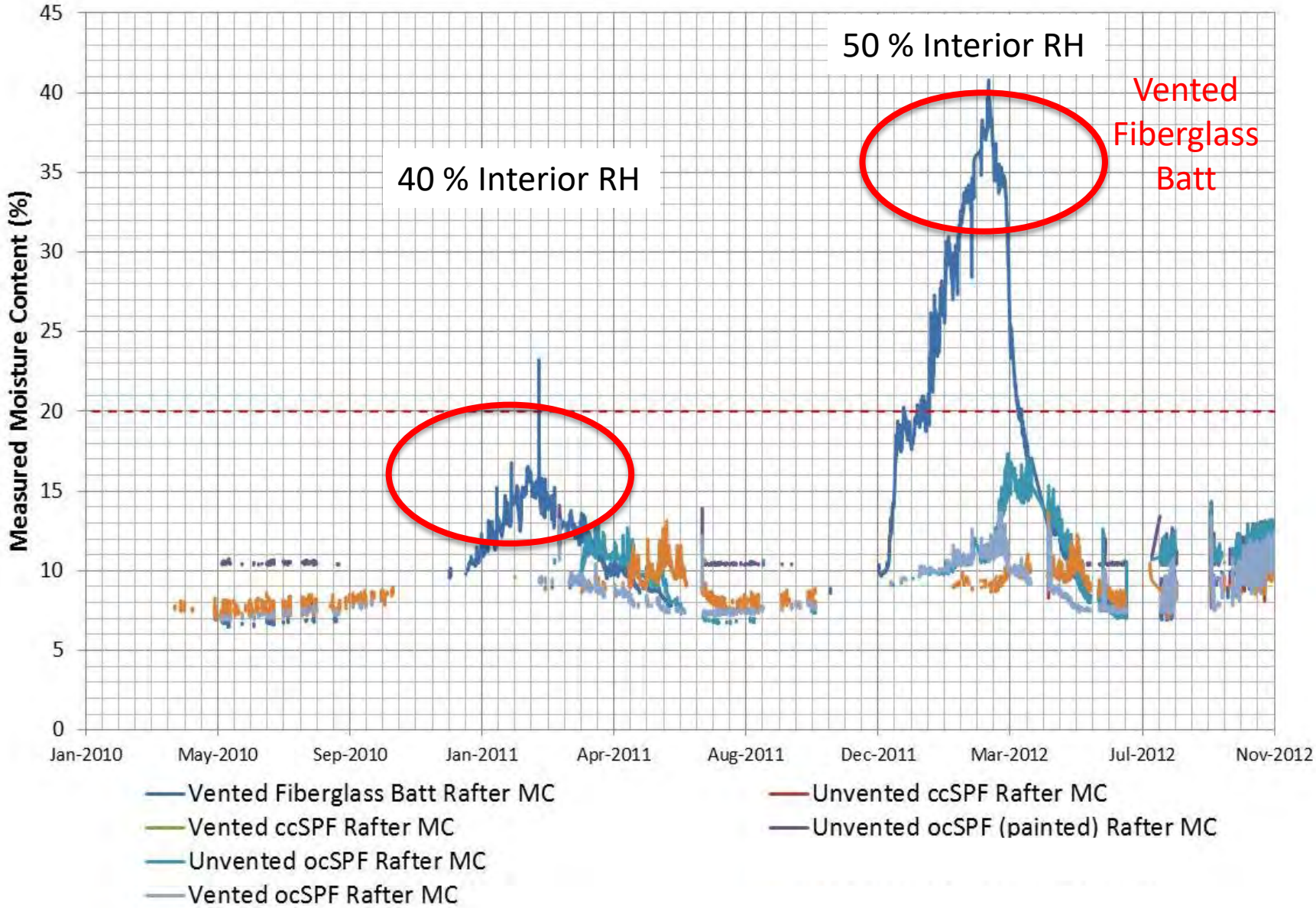


Test Assembly	Insulation	Ventilation	Vapor Control	Air Control
Unvented Closed Cell (NCC)	R30 (~5”)	No	ccSPF	SPF
Vented Closed Cell (VCC)	R30 (~5”)	Yes	ccSPF	SPF
Vented Fiberglass (VFG)	R30 (~9 ¼”)	Yes	Latex paint on drywall	Drywall
Unvented Painted Open Cell (NOCP)	R30 (~8”)	No	Paint on foam and drywall	SPF
Vented Open Cell (VCC)	R30 (~8”)	Yes	Latex paint on drywall	SPF
Unvented Open Cell (NOC)	R30 (~8”)	No	Latex paint on drywall	SPF

Measured Sheathing MC



Rafter MC

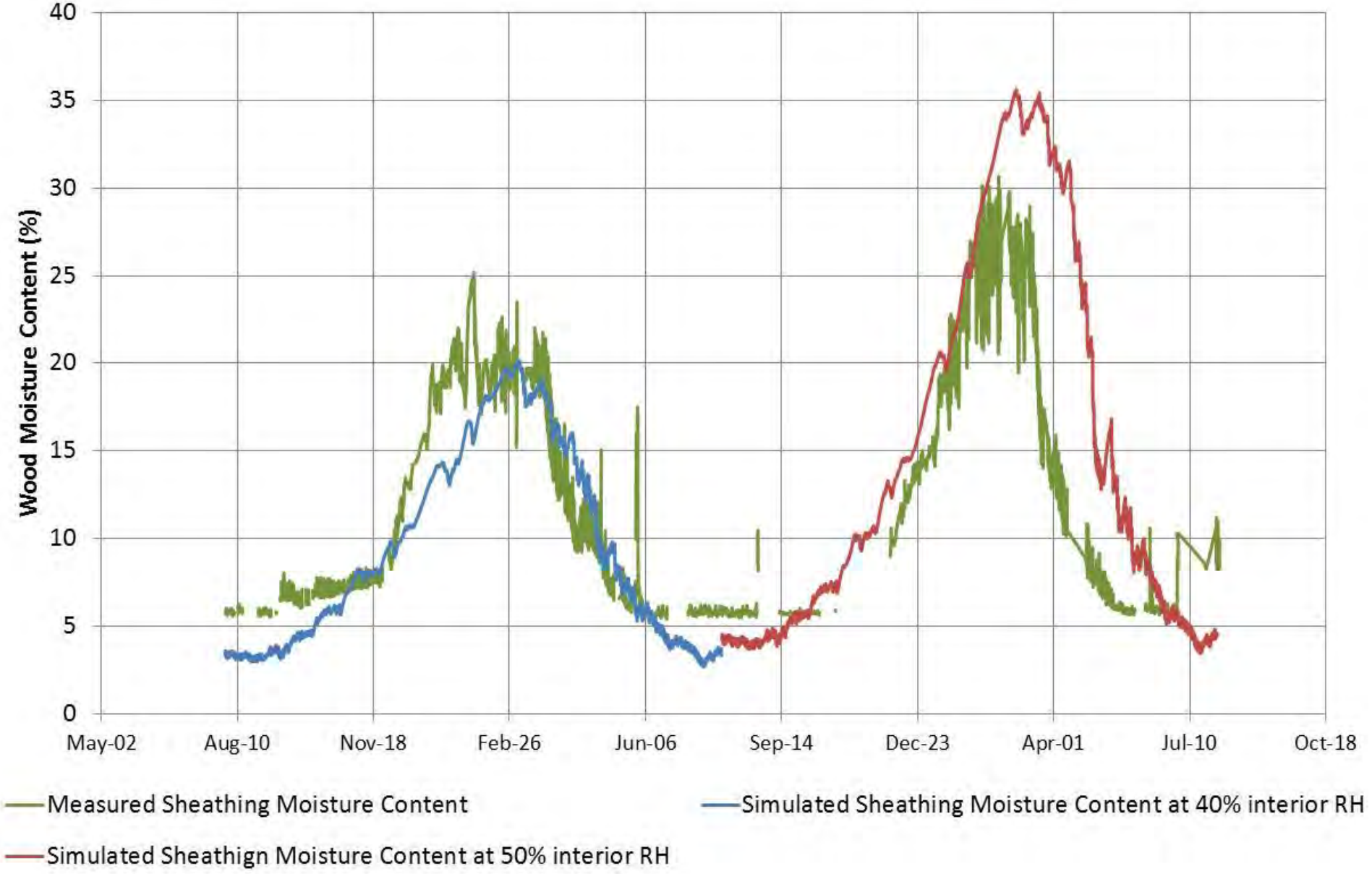

50 % Interior RH
Vented Fiberglass Batt
40 % Interior RH
Measured Moisture Content (%)
45
40
35
30
25
20
15
10
5
0
Jan-2010
May-2010
Sep-2010
Jan-2011
Apr-2011
Aug-2011
Dec-2011
Mar-2012
Jul-2012
Nov-2012
Vented Fiberglass Batt Rafter MC
Vented ccSPF Rafter MC
Unvented ocSPF Rafter MC
Vented ocSPF Rafter MC
Unvented ccSPF Rafter MC
Unvented ocSPF (painted) Rafter MC

Full Scale Field Testing

- Measured data is good to demonstrate, and assess performance in a specific region.
- Measured data has limitations including climate zone and boundary conditions.
- It’s not practical to conduct full scale tests in all climate zones on all assemblies
- Validate hygrothermal analysis data with measured data following monitoring

Correlation of measured and simulated data

- Correlation of monitored UW data with simulation data – Unvented ocSPF assembly
- Modifications made to worst case scenario simulations
  - East orientation
  - 4:12 slope
  - 40% interior RH first winter, 50% interior RH second winter
  - Waterloo weather file data


Wood Moisture Content (%)
40
35
30
25
20
15
10
5
0
May-02
Aug-10
Nov-18
Feb-26
Jun-06
Sep-14
Dec-23
Apr-01
Jul-10
Oct-18
Measured Sheathing Moisture Content
Simulated Sheathing Moisture Content at 40% interior RH
Simulated Sheathign Moisture Content at 50% interior RH

Hygrothermal Analysis

ASHRAE 90.1

Climate Zone	Thermal Criteria
4	2000 < HDD18°C ≤ 3000
5	3000 < HDD18°C ≤ 4000
6	4000 < HDD18°C ≤ 5000
7	5000 < HDD18°C ≤ 7000
8	7000 < HDD18°C

Cathedral Roof Construction					Vancouver HDD 3000			Toronto HDD 4000			Ottawa HDD 4500		
Contents of Cavity		Depth of Cavity	Ventilation	Type of Vapour Control	Low RH 30/55%	Med. RH 40/60%	High RH 50%	Low RH 30/55%	Med. RH 40/60%	High RH 50%	Low RH 30/55%	Med. RH 40/60%	High RH 50%
Spray Polyurethane Foam (SPF)	2.0 pcf Closed Cell[3]	5" R30	Ventilated Continuous Baffle	ccSPF	13%	13%	13%	10%	10%	10%	10%	10%	10%
		5" R30	Non-ventilated	ccSPF	11%	14%	14%	10%	13%	13%	12%	14%	14%
	0.5 pcf Open Cell	8" R30	Non-ventilated	interior poly	13%	13%	13%	13%	13%	13%	13%	14%	15%
		8" R30	Ventilated	latex paint	13%	13%	14%	11%	11%	11%	11%	11%	11%
		8" R30	Non-ventilated	1 US perm paint on foam	12%	17%	18%	13%	24%	28%	15%	30%	32%
		8" R30	Non-ventilated	latex paint	17%	30%	35%	25%	40%	50%	38%	52%	54%
Fiberglass Batt		9 1/4" R30	Ventilated Continuous Baffle	interior poly									
		9 1/4" R30	Ventilated Continuous Baffle	latex paint	16%	17%	17%	14%	14%	14%	13%	13%	13%

Other Applicable Locations
(Heating Degree Days below 18°C)

From Environment Canada's Canadian Climate Normals 1971-2000

Vancouver	Toronto	Ottawa
White Rock (2782)	Windsor (3524)	Kitchener-Waterloo (4288)
Vancouver (2926)	Niagara Falls (3661)	Kingston (4289)
Abbotsford (2981)	Kelowna (3869)	Montréal (4518)
Victoria (3040)	Oshawa (3917)	Moncton (4585)
	Hamilton (4012)	Ottawa (4602)
	Halifax (4030)	Charlottetown (4715)
	London (4057)	
	Toronto (4065)	

In-service Inspections

- Numerous published field surveys
- In-service buildings, 3 to 10+ years old
- Usually top-side sheathing inspections
- No observed systemic issues
  - *Small* leaks dry out

- Forensic experience: less public info. Failures do occur due to bad workmanship, mistakes

Conclusions

- Unvented pitched wood-frame roofs
  - **Can** and **do** work
  - Science and Field experience
  - No good reason for code to block
- ccSPF requires proper workmanship, (of course)
  - Airtightness!
- We need some vapor diffusion control
  - Colder climates, high interior RH require low perm
- Control interior RH
  - As per NBCC for example