# Controlling Mold Growth in Ventilated Wood-Frame Attics in BC's Cool Marine Climate

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Homeowner Protection Office
Branch of BC Housing

POLYGON
polyhomes.com

Morrison Hershfield

# Acknowledgements

- Morrison Hershfield collaborated with  several industry partners
    - Homeowner Protection (HPO), branch of BC Housing
    - FP Innovations
    - Polygon Construction Management
    - University of British Columbia’s School of Population and Public Health

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# Why Ventilate?

- Most building codes stipulate prescriptive ventilation requirements to minimize condensation and moisture collection in attics
- The lack of ventilation is routinely blamed for a variety of problems and failures

**Staining at the location where the ventilation rate should be the highest?**



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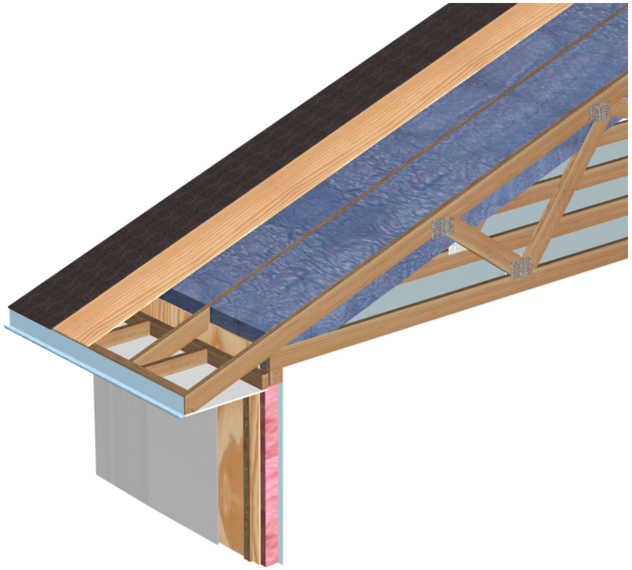
# Why Ventilate?



## Additional cited benefits include:

- summer cooling of the attic and reducing loads in hot climates
- minimizing ice dams in cold climates
- extending the service life of roof materials by reducing material temperatures

**The real significance of some of these benefits and the mandatory requirement for venting for all types of roof construction has come into question**

# Is Surface Mold Outside a Problem?

# Is Surface Mold in the Attic a Problem?

The molds in the attic are surface molds that are abundant in our environment

Mold anywhere is not acceptable and must be eliminated

**Marketability and Property Values**

Mold in attics will not increase exposure in the indoor space

**There is an impact despite experts concluding there are no real health risks or cause of concern for accelerated material degradation if all attics do not have mold**

# Study Objectives

- Demonstrate that passive attic ventilation is not enough to control moisture in, and fungal growth on, wood sheathing and framing in well insulated attics in cool marine climates

✓ Code required venting area and distribution

✓ Good practice for ceiling air-tightness

✓ Low to moderate indoor humidity

✓ **Mold Growth**



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# The Canadian Experience

- Several field studies in the 1990's sponsored by CMHC
- Most identified that the leading cause of moisture troubled attics is due to the transfer of moist indoor air into the attic space from **high humidity indoor** spaces
- The general assumption is that if the ceiling is reasonably **air-tight** and you have the code required attic ventilation then there is **little potential for moisture collection**

# University of Alberta Study (1993)

## Two test houses in Edmonton

- one with no intentional attic ventilation openings and
- one with traditional soffit and roof venting
- validated heat-air-moisture model with good agreement between measured and simulated results

## Contrary conclusions for Marine climates

- Dominant moisture source is the outdoor air
- Ceiling air-tightness had little impact on sheathing MC
- Attic moisture levels can be substantially reduced by not installing any vents (roof or soffit) and relying only on the background leakage of the attic envelope

# It's not just a Canadian Wet Coast thing

## Europe – Leuven, Belgium (1970s)

- A lot of work on attic ventilation in the 1970s, mainly as a consequence of complaints about mold and condensation in attic spaces

## Key Findings and Consequences

- Ventilation has risks in a moderate but humid climate
- Better to provide an air-tight ceiling, provide some outboard thermal resistance, and avoid pressurizing the indoor space
- Cathedral ceilings became popular

# It's not just a Canadian Wet Coast thing

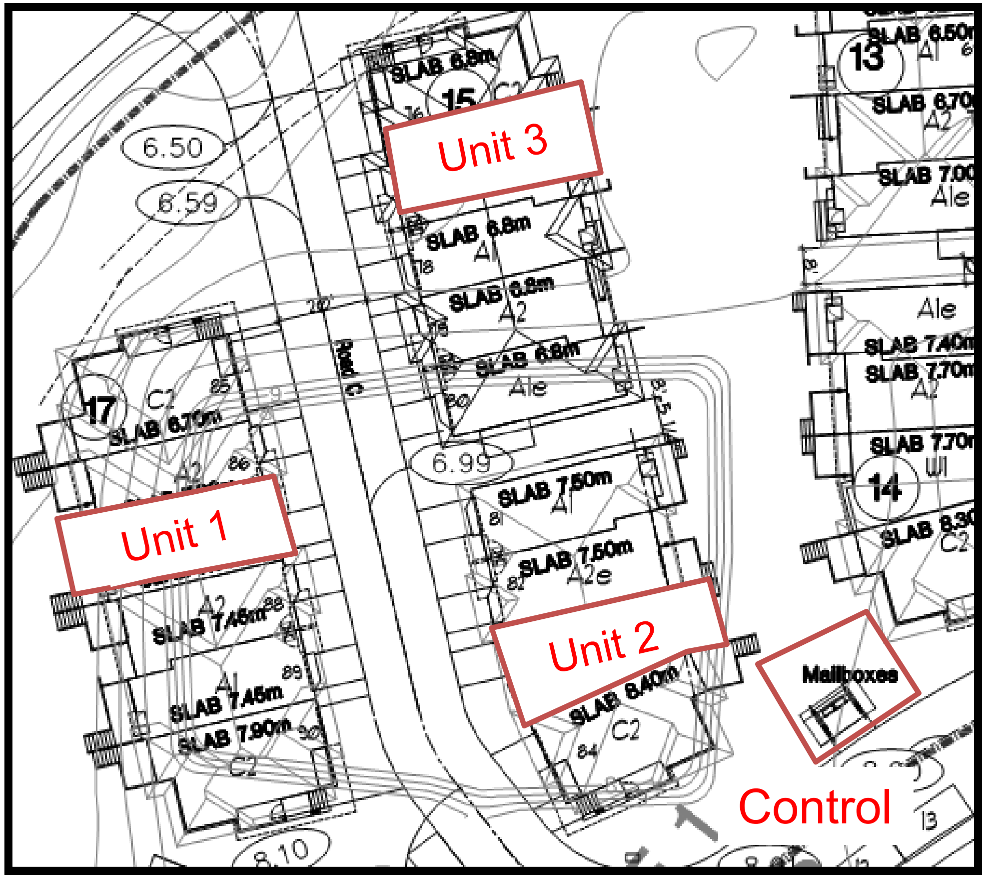
## Europe – Gothenburg, Sweden (Present)

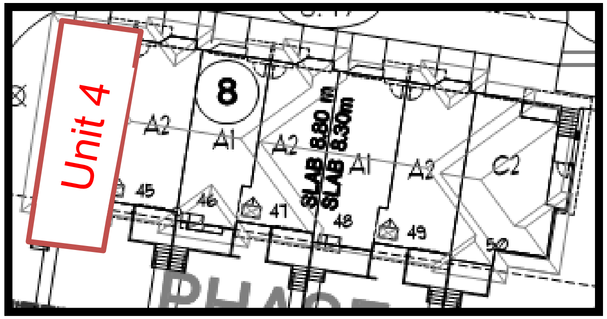
- Recent survey indicates that as many as many as 60% to 80% of existing buildings around Gothenburg have mold in the attics

## Key Findings and Consequences

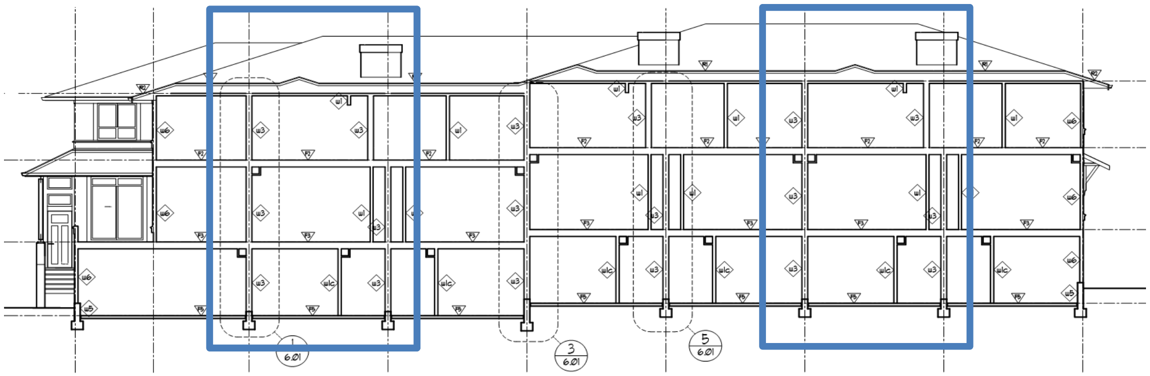
- Research on controlled and adaptive ventilation
- Field tests and heat-air-moisture simulations
- Risk of mold growth can be decreased through more stable and lower RH levels during the winter than traditional ventilation strategies

# Study Overview



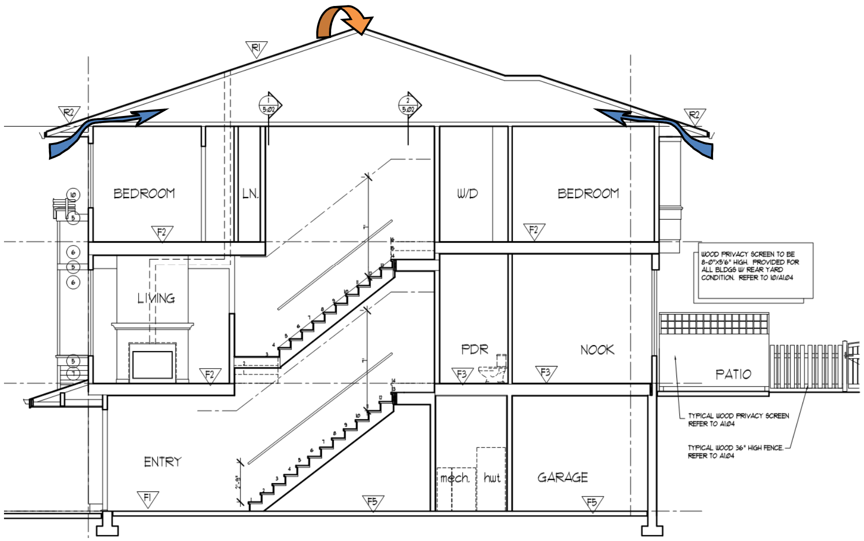



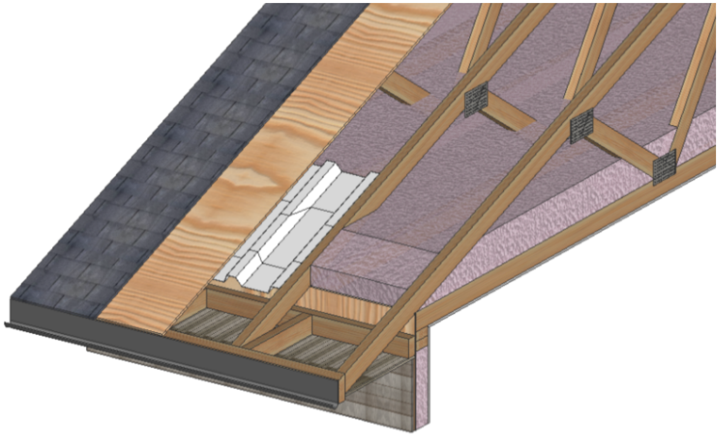
# Study Overview



# Study Overview

# Attic Construction and Ventilation





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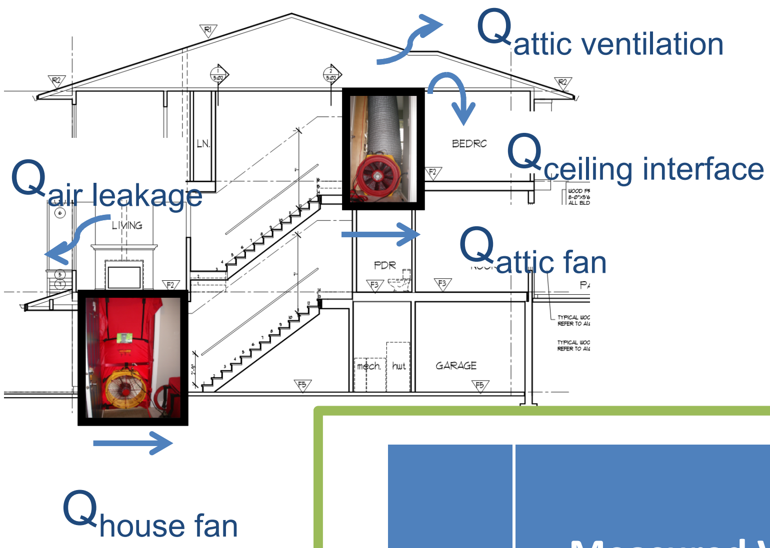
# This is not from leaky shingles!

# Building Characterization: Attic Ventilation Area




| Unit | Measured Venting Area | Insulated Area m² (ft²) | Required Area (1/300 per insulated ceiling area) | % Measured Area / Required Area |
|---|---|---|---|---|
| 1 | 2450 cm2 @ 40 Pa | 60 (642) | 1900 cm2 | 129% |
| 2 | 2435 cm2 @ 40 Pa | 68 (728) | 2160 cm2 | 113% |
| 3 | 3900 cm2 @ 40 Pa | 57 (614) | 1990 cm2 | 196% |
| 4 | 7530 cm2 @ 15 Pa | 60 (642) | 2315 cm2 | 325% |

# Building Characterization: Interface Leakage

| Suite | Measured Leakage Area | Calculated Normalized Leakage Area $cm^2/m^2$ @ 10 Pa (NLA) | Smoke Test |
|---|---|---|---|
| 1 | 110 $cm^2$ @ 40 Pa | 1.6 | Smoke at hatch |
| 2 | 110 $cm^2$ @ 40 Pa | 1.4 | Smoke at hatch and the fresh air vent in the bedroom closet |
| 3 | 160 $cm^2$ @ 40 Pa | 2.2 | Smoke at hatch and the fresh air vent in the washer/dryer closet |
| 4 | 300 $cm^2$ @ 15 Pa | 4 | Smoke at hatch (less than others) |

# Building Characterization: Interface Leakage

## The ceiling to attic interface is air-tight

- NLA values for units 1 and 2 are lower than all the ceiling to attic interface leakage areas for a study of eight attics that included three houses that had whole air tightness testing to confirm 1.5 ACH @ 50 Pa or a NLA of 0.7 $cm^2/m^2$ (R-2000 house)
- Even unit 4 has a lower NLA than some of the R-2000 houses in BC

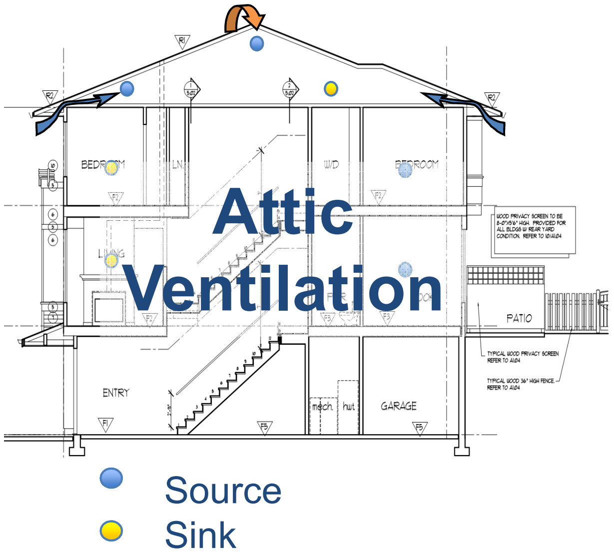
NLA from 1997 Survey By National Resources Canada

| Region | 1981-1990 | 1991-1997 | R-2000 |
|---|---|---|---|
| B.C. | 2.8 | 1.9 | 0.7 |
| National | 2.3 | 1.4 | 0.6 |

# Tracer Gas Testing: Air Transfer Measurement

## The attic ventilation rate was low

- Not much wind pressure to drive air flow (low wind speed and sheltered units)
- Not much thermal forces to drive air flow (1 to 2°C average temperate difference)

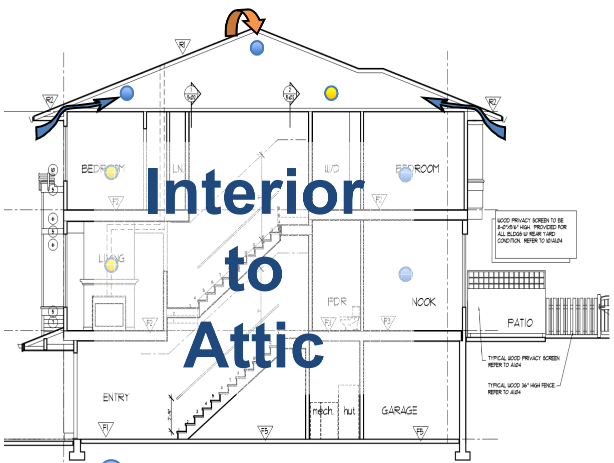



| Unit | Attic Ventilation ACH ($m^3/h$) | | Derived from Fan Testing |
|---|---|---|---|
| | Round 1 Dec. 8 to 15 | Round 2 Feb. 20 to 27 | ACH ($m^3/h$) @ 4 Pa |
| 1 | 1.2 (69.9) | 1.0 (61.1) | 8.3 (488) |
| 2 | 1.3 (75.7) | 1.2 (73.4) | 8.3 (485) |
| 3 | 2.6 (112.8) | 3.7 (91.9) | 18.2 (778) |
| 4 | 4.1 (102.4) | 2.1 (123.0) | 58.7 (1475) |

# Tracer Gas Testing: Air Transfer Measurement

## The transfer of air from interior to attic was moderately low

- Rates much lower than eight units tested for normal housing stock (1991)
- Rates higher than in two research houses
- Less stack pressure than 4 Pa




Source
Sink

| Unit | Interior to Attic CFM ($m^3/h$) | | Derived from Fan Testing |
|---|---|---|---|
| | Round 1 Dec. 8 to 15 | Round 2 Feb. 20 to 27 | CFM ($m^3/h$) @ 4 Pa |
| 1 | 16.5 (28.0) | 11.4 (19.3) | 26.2 (44.5) |
| 2 | 16.4 (27.8) | 8.5 (14.4) | 26.2 (44.5) |
| 3 | 18.8 (32.0) | 11.7 (19.9) | 38.1 (64.7) |
| 4 | 18.5 (31.4) | 12.6 (21.4) | 82.7 (140.5) |

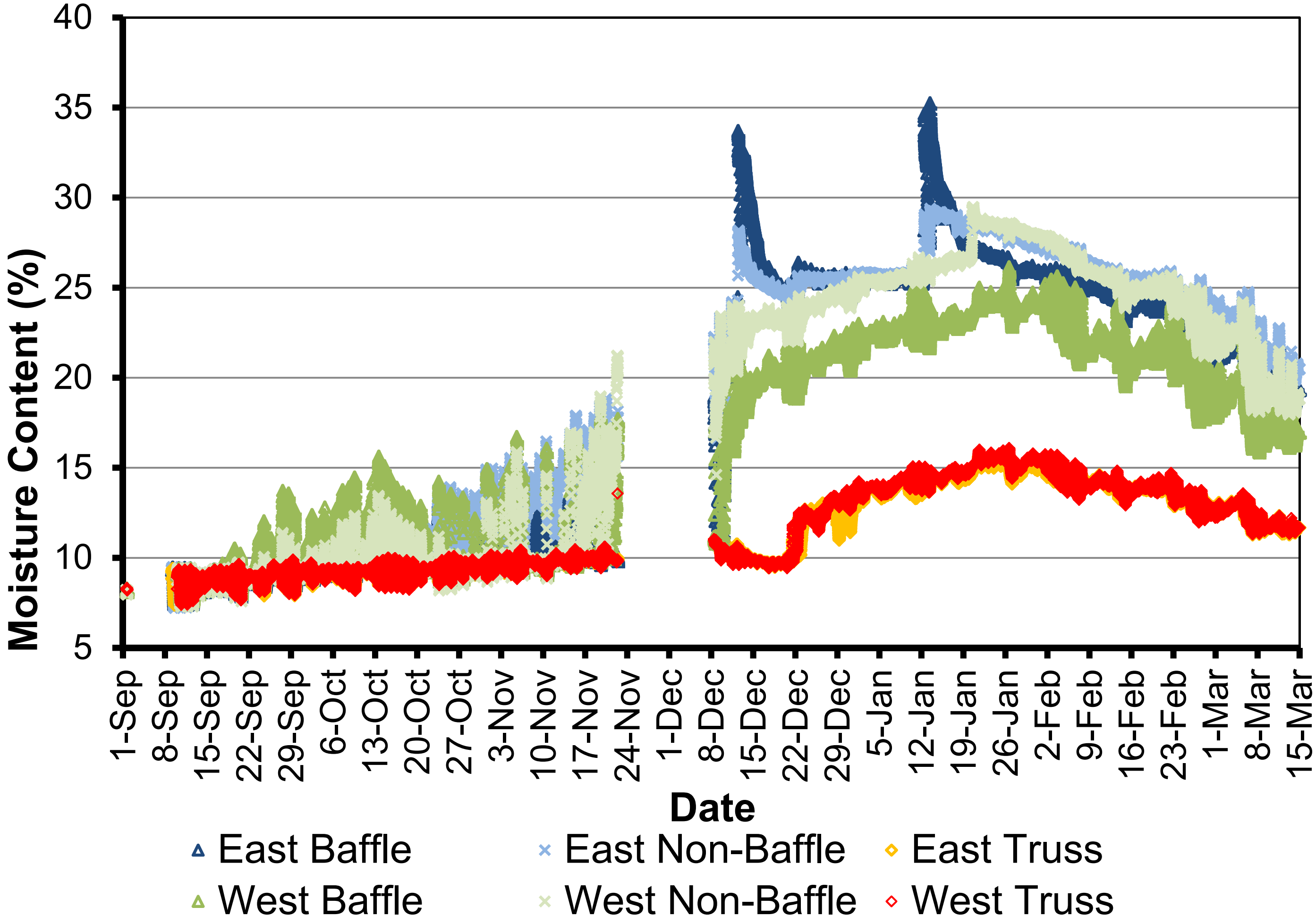
# Monitoring Results

## The indoor moisture was low to moderate

- Many previous Canadian studies indicated that moisture problems in attics were generally not evident without high indoor RH
- The units in this study do not follow this trend


| Unit | Average Temperature (°C) | Average RH (%) | 95% Percentile Dewpoint Temperature (°C) | Average DVP (Pa) | 95% Percentile DVP (Pa) | 99% Percentile DVP (Pa) |
|---|---|---|---|---|---|---|
| Outdoors | 6.9 | 84.4 | 8.5 | N/A | N/A | N/A |
| 1 | 24.1 | 30.7 | 9.3 | 250 | 600 | 750 |
| 2 | 22.1 | 40.7 | 10.7 | 250 | 450 | 550 |
| 3 | 19.1 | 37.5 | 7.1 | 0 | 200 | 300 |
| 4 | 23.3 | 32.8 | 9.0 | 100 | 300 | 500 |

# Monitoring Results
# Long-Term Trends (Unit 2)



# Plywood Sheathing Staining



| Unit | Moderate to Heavy – Field Area Spotty or Covered | Light – localized at Fasteners | No visible Staining |
|---|---|---|---|
| 1 | East: baffle | East: non-baffle,<br>West: baffle & non-baffle | East: truss<br>West: truss |
| 2 | East: baffle | East: non-baffle<br>West: baffle & non-baffle | East: truss<br>West: truss |
| 3 | West: baffle | East: baffle & non-baffle<br>West: non-baffle | East: truss<br>West: truss |
| 4 | North: non-baffle | North: baffle | South: baffle &non-baffle<br>South: truss |



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# Observed Staining and Measured Moisture Levels

- Does not account for variable temperatures and RH
- Does not account for time
- Difficult to assess the impact of wetting by condensation
- Control was above 19% MC longer than the attics, but not much time above 25% MC

| Unit | Location | Observed Mold Index | | | Weeks above 25% MC | | Weeks above 28% MC | |
|---|---|---|---|---|---|---|---|---|
| | | at Nov. 2011 | at Nov. 2012 | at Apr. 2013 | Winter of '11/'12 | Winter of '11/'12 | Winter of '11/'12 | Winter of '12/'13 |
| 1 | East Baffle | 4 | n/a | 5 | 7.5 | 2 | 1 | 0.5 |
| | East non-baffle | 3 | n/a | 4 | 10 | 2.5 | 4 | 0.5 |
| | West Baffle | < 3 | n/a | <3 | 0 | 0 | 0 | 0 |
| | West non-baffle | < 3 | n/a | <3 | 0 | 0 | 0 | 0 |
| 2 | East Baffle | 4 | 5 | 5 | 7.5 | 9 | 1 | 2.5 |
| | East non-baffle | 3 | 4 | 4 | 9 | 11 | 2 | 2.5 |
| | West Baffle | < 3 | < 3 | 4 | 0 | 7.5 | 0 | 0.5 |
| | West non-baffle | 3 | 3 | 3 | 6 | 9.5 | 1 | 1.5 |
| Control | With Insulation | 0 | n/a | 4 | 0 | 2.5 | 0 | 0 |
| | Without Insulation | 0 | n/a | 4 | 0 | 3 | 0 | 0 |

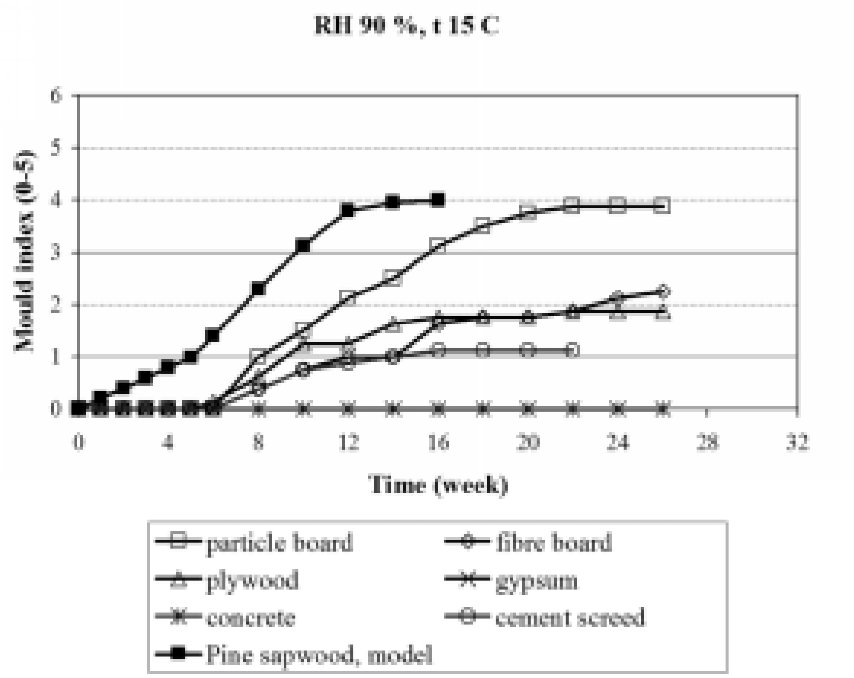
# Mold Index

## Tool to compare observations and measurements to a predictive model

0. No growth
1. Growth detected by microscope
2. Moderate growth detected by microscope (coverage more than 10%)
3. **Growth visually detected**
4. Moderate growth, 10 to 50% visual coverage
5. High growth, visual coverage more than 50%
6. 100% visual coverage

# Mold Index

- In concept, accounts for exposure time, temperature, and RH concurrently
- Single indicator for evaluating mold risk
- Can not predict absolute mold growth with the given unknowns
- **A good yardstick**





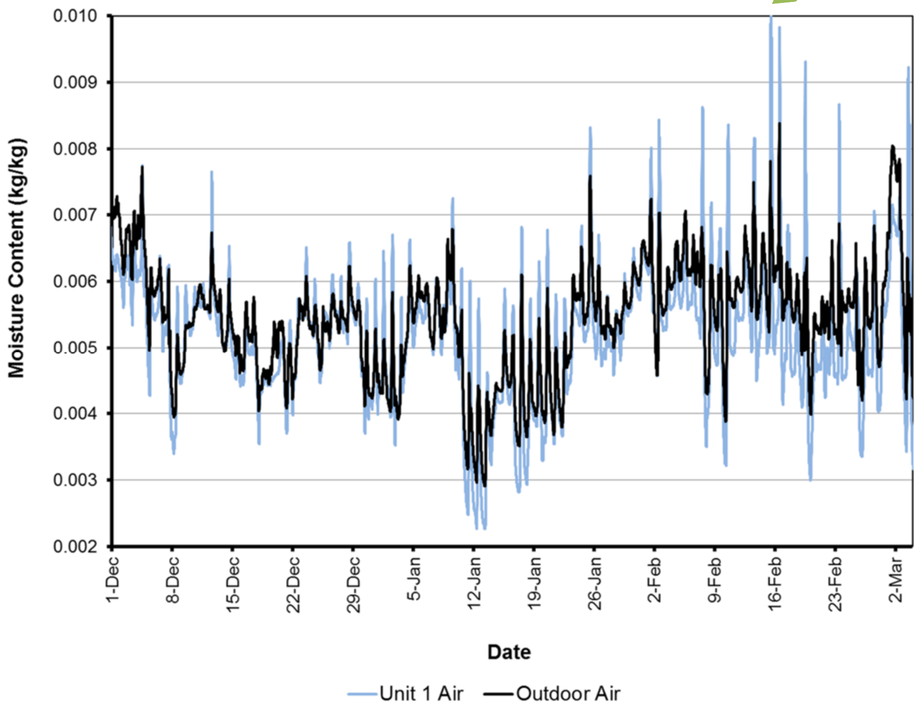

Source – Viitanen and Ojanen "Improved Model to Predict Mold Growth in Building Materials" 2007

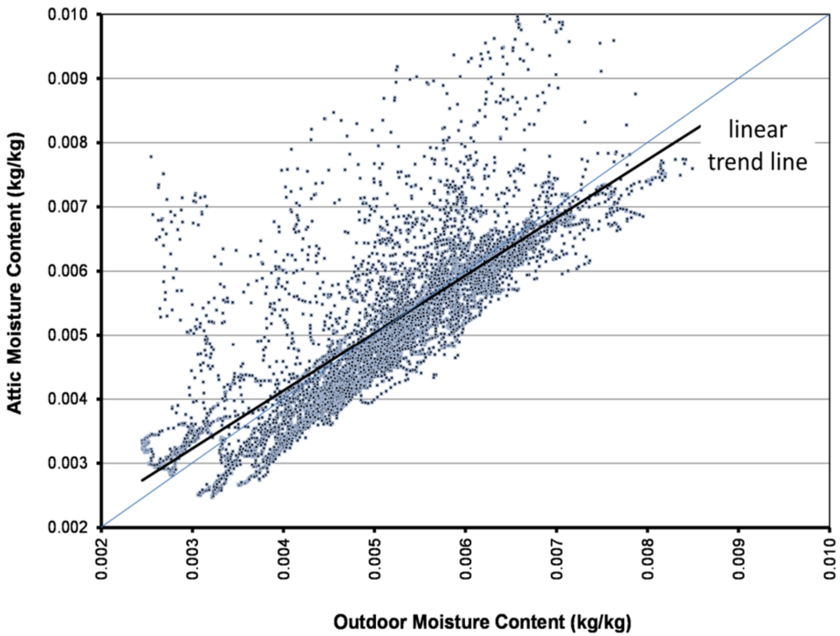
# Observed vs. Predicted Mold Index

| Unit | Location | Observed Mold Index | | | Predicted Mold Index | |
|---|---|---|---|---|---|---|
| | | at Nov. 2011 | at Nov. 2012 | at Apr. 2013 | Winter of ‘11/’12 | Winter of ‘12/’13 |
| 1 | East Baffle | 4 | n/a | 5 | 4 | 4.5 |
| | East non-baffle | 3 | n/a | 4 | 3.5 | 4 |
| | West Baffle | < 3 | n/a | < 3 | < 3 | < 3 |
| | West non-baffle | < 3 | n/a | < 3 | < 3 | < 3 |
| 2 | East Baffle | 4 | 5 | 5 | 4.5 | 5 |
| | East non-baffle | 3 | 4 | 4 | 4.5 | 5 |
| | West Baffle | < 3 | < 3 | 4 | < 3 | 4.5 |
| | West non-baffle | 3 | 3 | 3 | 4 | 5 |
| Control | With Insulation | 0 | n/a | 4 | n/a | 4 |
| | Without Insulation | 0 | n/a | 4 | 4 | 4 |

# Monitoring Results
# Long-Term Trends

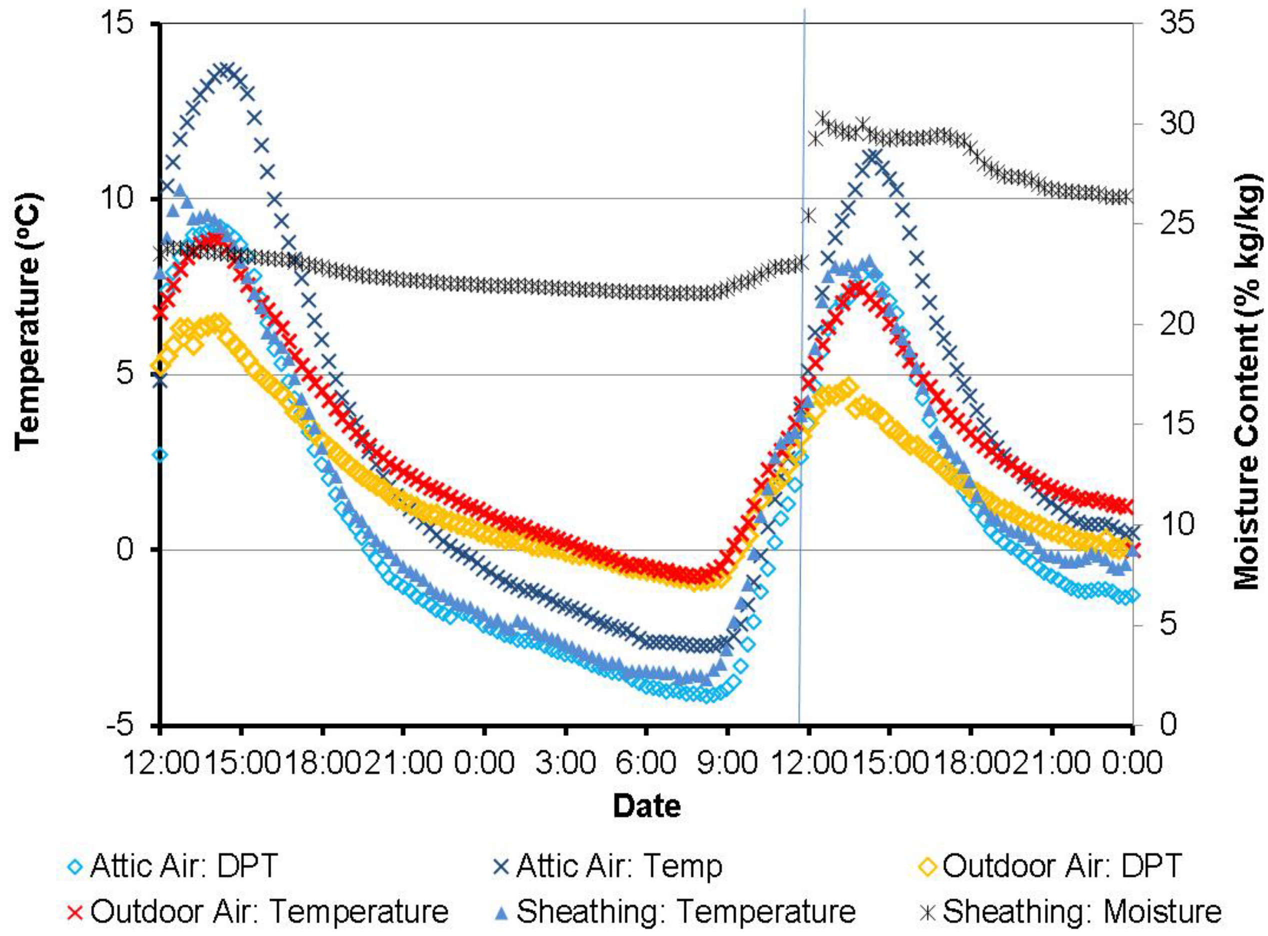
Decreasing moisture levels in the sheathing and elevated temperatures




## Outdoor air is the principal moisture source

# Monitoring Results
# Diurnal Wetting

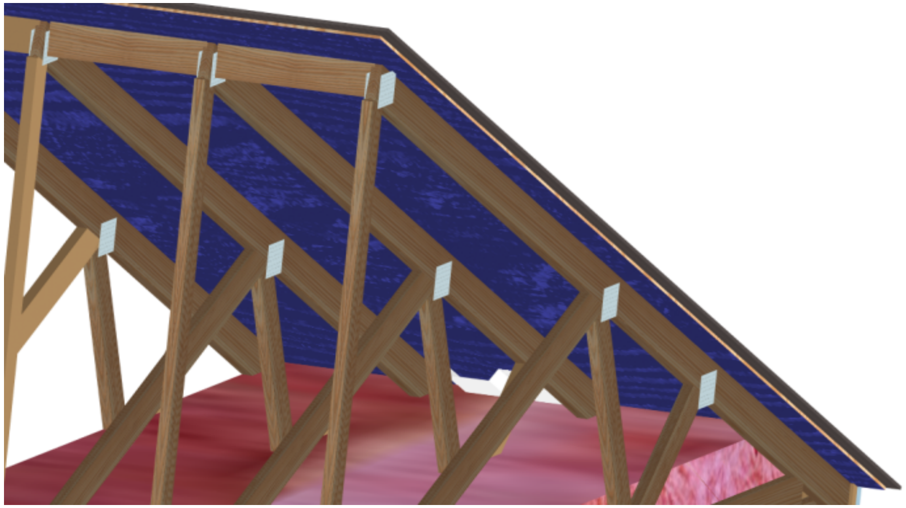


# Conclusions of Phase 1

- **Staining of the roof sheathing can occur in attics that:**
  - Represent current good practice
  - Are connected to indoor spaces with low to moderate humidity levels
  - Do not have excess moisture loads in the attic spaces from duct leakage, plumbing, or transfer of air from the indoor space.

# Phase Two Objectives

1. Answer questions regarding the relative influence of factors that affect mold growth in ventilated attics in the lower mainland of BC, and
2. Develop possible strategies to reduce the likelihood of visible mold growth and/or wetting occurring in wood-frame attics.





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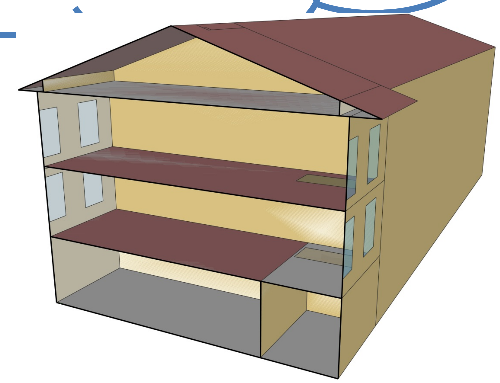
# Factors Leading to Fungal Growth

Answer questions regarding the relative influence of factors that affect moisture levels in attics

- Ceiling air-tightness, ventilation rates, sheathing thermal resistance, roof colour, and insulation levels

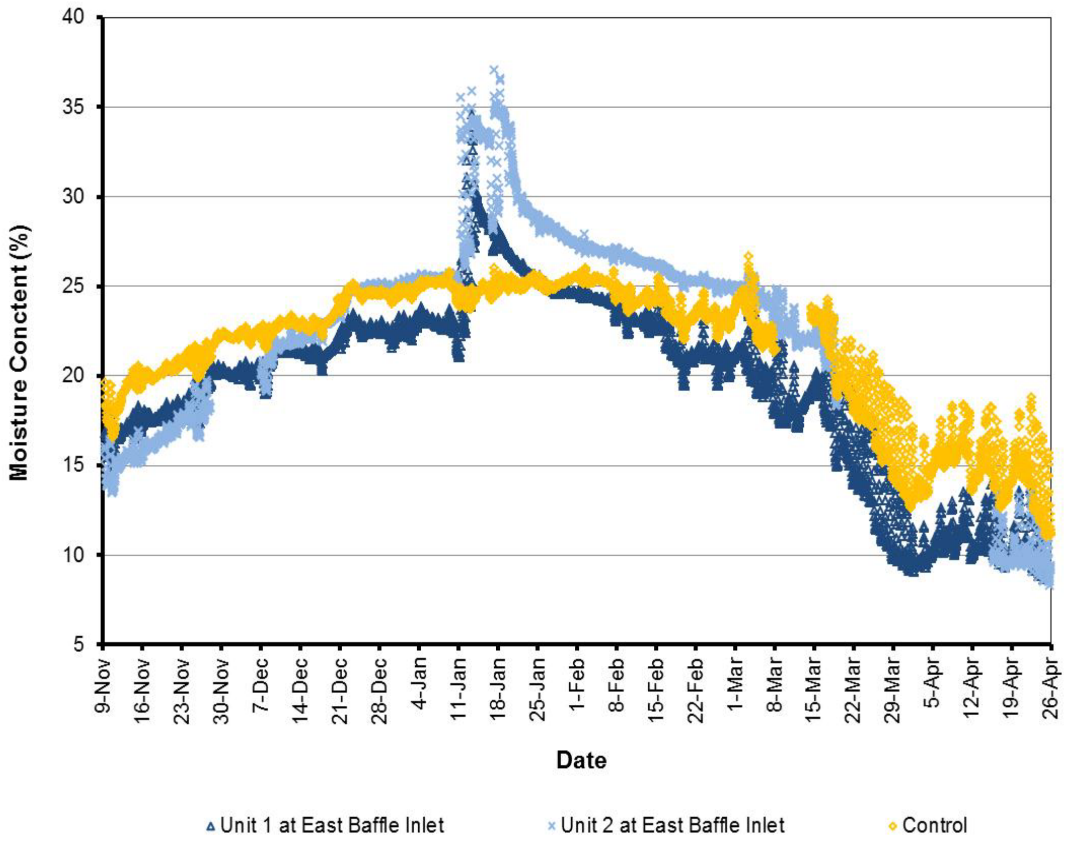
Additional monitoring

Heat-air-moisture (HAM) simulations



# Impact of Venting Area: Key Observations

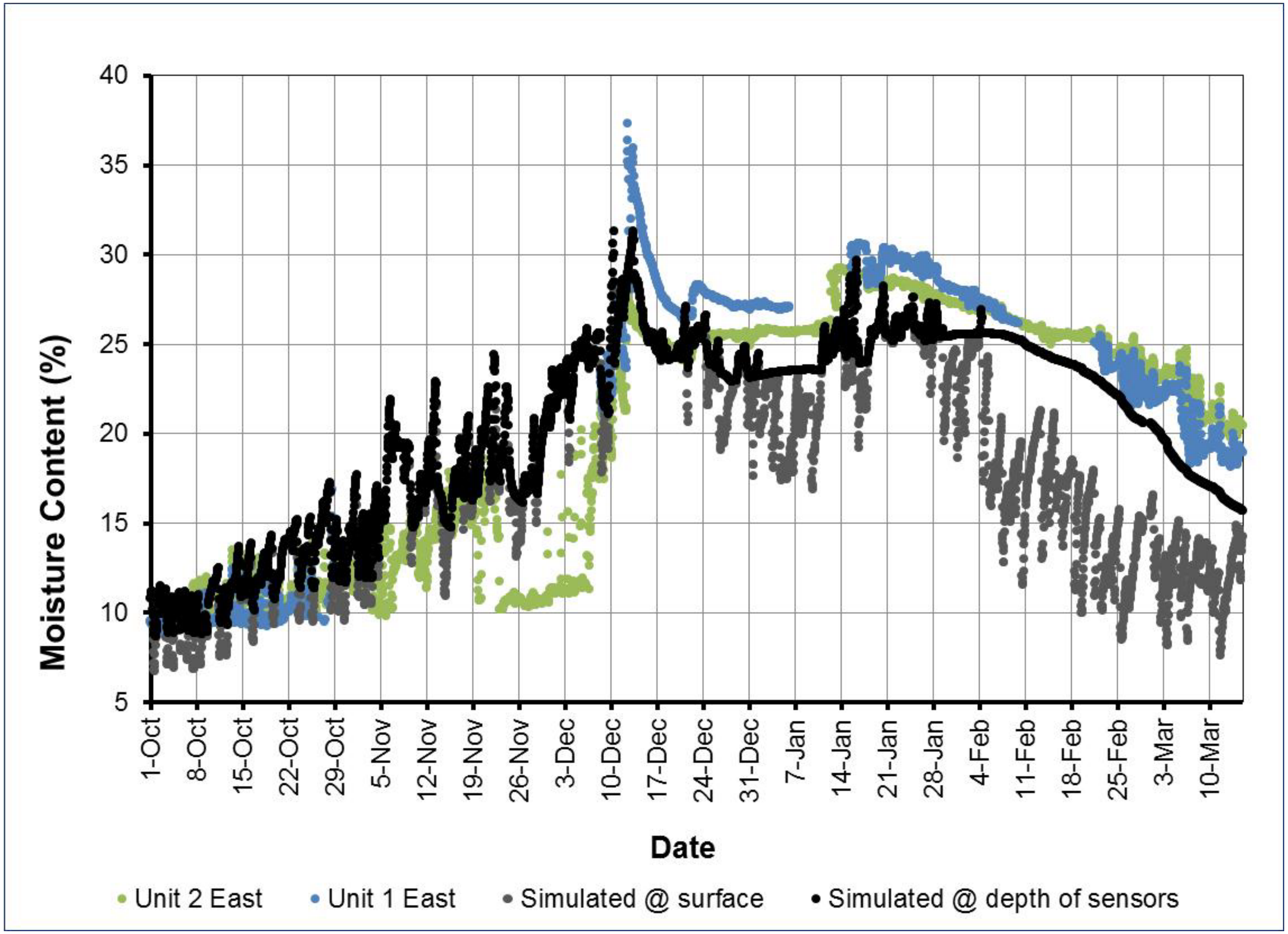
- Unit 1 has an additional vent
- Unit 2 has blocked soffit vents
- Unit 2 remained elevated for at least 6 weeks longer



# Cancel the Roof Hacking

- There was no real benefit in terms of the mold index
- The risk of mold did not appear to be reduced

# Validation of the Monitoring Data and HAM Model



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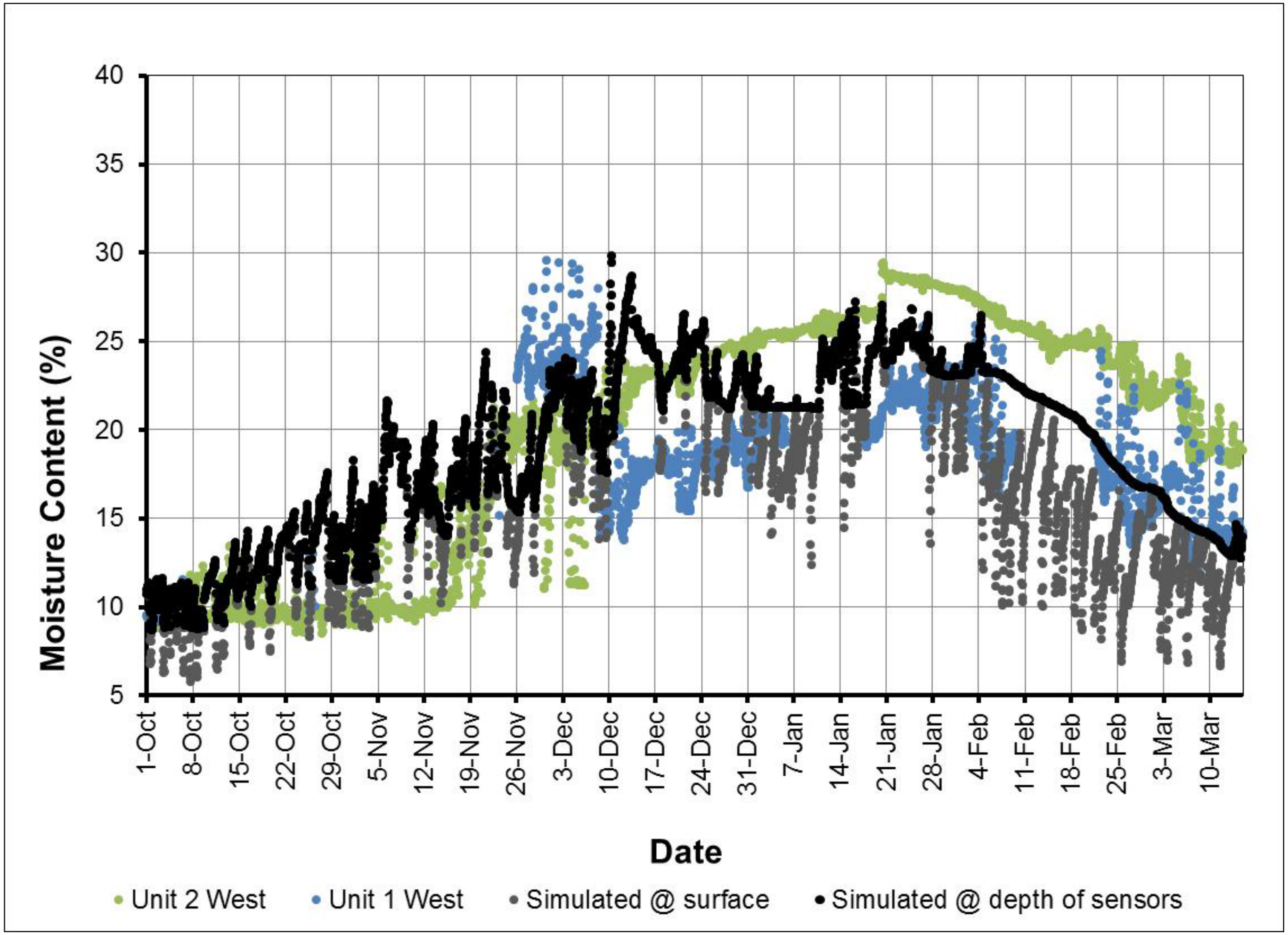




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# Solution Roadmap

**Strategy 1.** Treat wood sheathings with chemicals that make exposed surfaces unfavourable for mold growth for a broad range of environmental conditions

**Strategy 2.** Provide insulating boards outboard mold resistant sheathings

**Strategy 3.** Provide all the roof insulation outboard the roof sheathing, keep the roof structure warm and dry, and eliminate the need for a ventilated attic

**Strategy 4.** Insulate the underside of the roof sheathing with foam insulation with an unvented roof assembly

**Strategy 5.** Provide a mechanical system that controls air flow into the attic space and only ventilates when there is not the potential to add moisture to the attic space

# Design Solutions

- **Select designs that do not require ventilation**
- **Warm up the surface of the roof sheathing**



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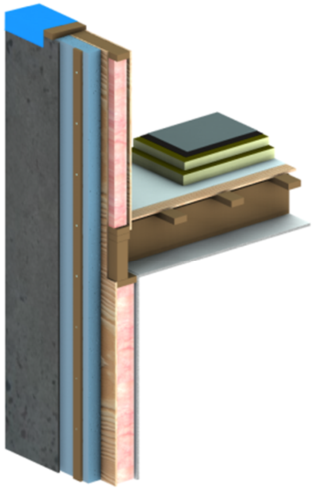
# Design Solutions

## Solution 3A

Conventional Low-sloped Roof Assembly



**Exterior**

- 2 PLY SBS roof membrane (water penetration and air barrier)
- Protection board
- Insulation
- Vapour barrier
- Roof sheathing sloped to drain
- Roof structure with gypsum ceiling

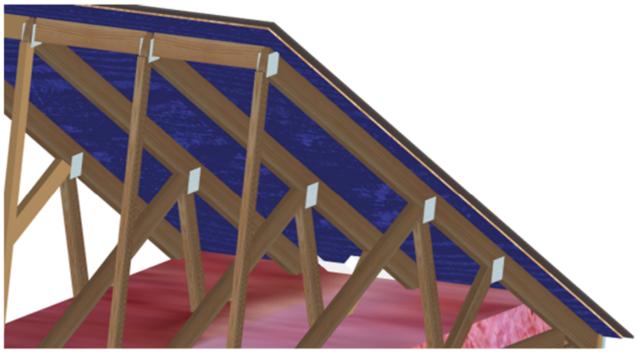
**Interior**

| | |
|---|---|
| **Construction Methods**: common | **Performance**: proven |
| **Cost**: moderate (between $2500 and $15,000 per unit) | **Uncertainties**: none |
| **Advantages**: proven good performance. | |
| **Disadvantages**: roof membrane is exposed and traffic should be minimized on the membrane. | |

# Chemical Treatments

## Solution 1.A

## Multi-functional Treatments for New Construction



Apply an all in one treatment to roof sheathing prior to delivery to job site. Bluwood is an example product.

| | |
|---|---|
| **Construction Methods**: enhanced | **Performance**: limited history |
| **Cost**: Low (less than $2500 per unit) | **Uncertainties**: Acceptance by PMRA, validation by AWPA E24-06 testing, long-term mold resistance when subject to wetting by condensation. |
| **Advantages**: wood is treated for surface molds, decay, insects, and warranties are available for long-term performance. The treatment colours the wood so it is evident that the product has been applied. Application is done in a control setting. | |
| **Disadvantages**: only applicable for new construction. | |

# Chemical Treatments

**What is the long term efficacy of chemical treatments?**

The identification of effective long lasting moldicides.

We envision more research in the following areas:

1. Validating products through controlled and repeatable lab testing
2. Demonstration projects to establish good practices for cleaning and treating wood products in attics and verifying acceptable field performance



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# Solutions – Cleaning and Dealing with Existing Mold

- Soap, water, and scrubbing is problematic in attics with low slopes near the soffit area (though we know of abatement companies recommending removing the ceiling to do this)
- Dry-ice blasting, or other media blasting, is an option.  However, this is more costly, cleaning up is problematic, and proper clean-up requires temporary removal of the insulation

# Can we Learn to Live with Mold in our Attics?

Avoid the collective cost of treating materials used in numerous buildings to resolve minor concerns in a few

This is likely to be a long process of:

- More research to confirm that mold growth in attics does not lead to health concern or accelerated deterioration of materials
- A program of education and discourse with the public

# Additional Unresolved Questions and Research

- What are the limits of concern?
  - Geographic
  - Other ventilated cavities

# Thank You