FIELD MONITORING OF HYGROTHERMAL PERFORMANCE OF ATTIC VENTING SYSTEMS IN EXTREME COLD CLIMATES

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Contents

- Introduction
- Experimental Setup
- Results and Discussion
- Conclusions

1. Introduction

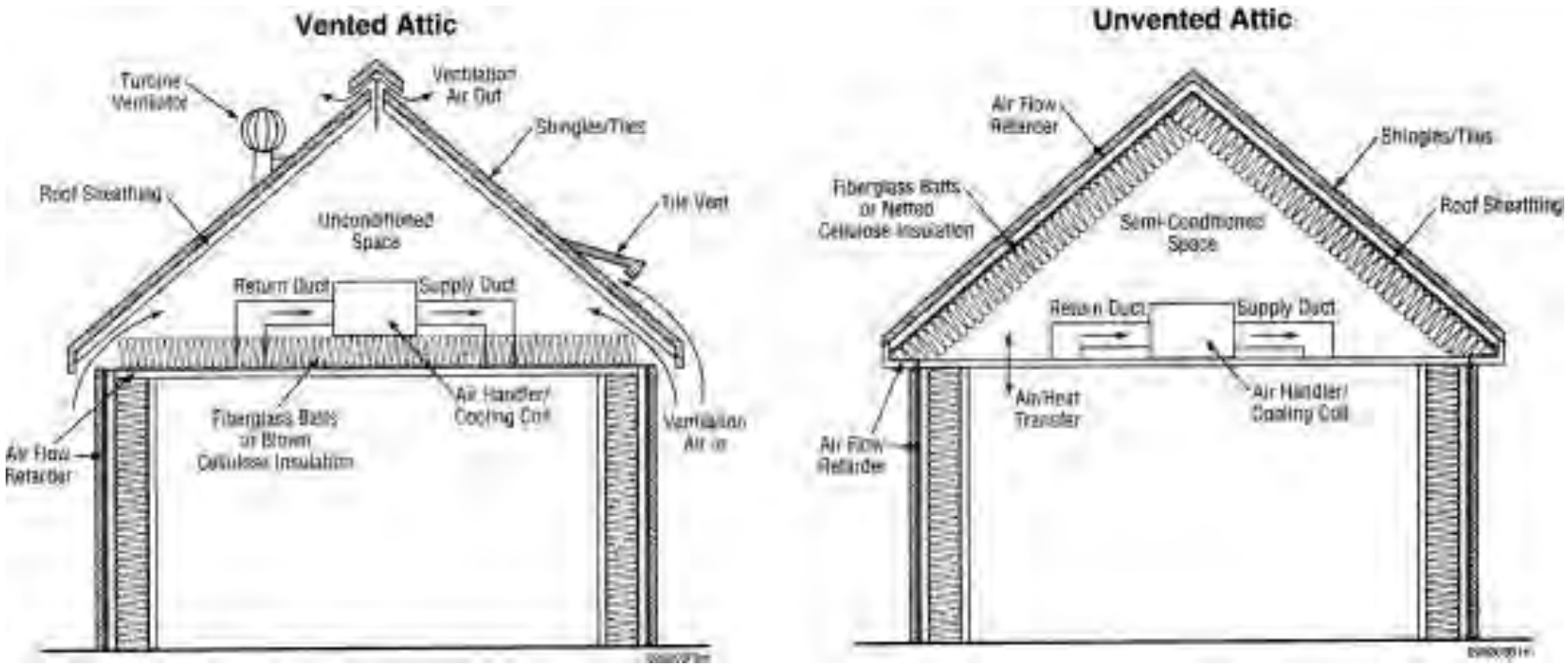
- 42 isolated communities in Nunavut and Nunavik (Northern Quebec), only accessible by air or water

Housing Challenges

- High costs of goods (building materials)
- Shortage of skilled labor
- Total dependence on fossil fuels
- Shortage and Overcrowded housing
- Durability issues

1. Introduction

- Ventilated Attic VS. Unventilated Attic



Source (Thermal Performance of Unvented Attics in Hot-Dry Climates: Results from Building America, Robert Hendron et al., 2004)

1. Introduction

Attic design in extreme cold climates

- **Issue:** snow accumulation with attic ventilation
- **Solutions:**
  - ✓ Cathedral roof
  - ✓ Ventilated attic with filter membrane to capture snow
  - ✓ Attempts with un-ventilated cold attic

Objective

- Investigate the hygrothermal performance of ventilated and un-ventilated attics in Canadian North through field measurements

2. Experimental Setup

- Test houses

2. Experimental Setup

➢ Test houses

House I

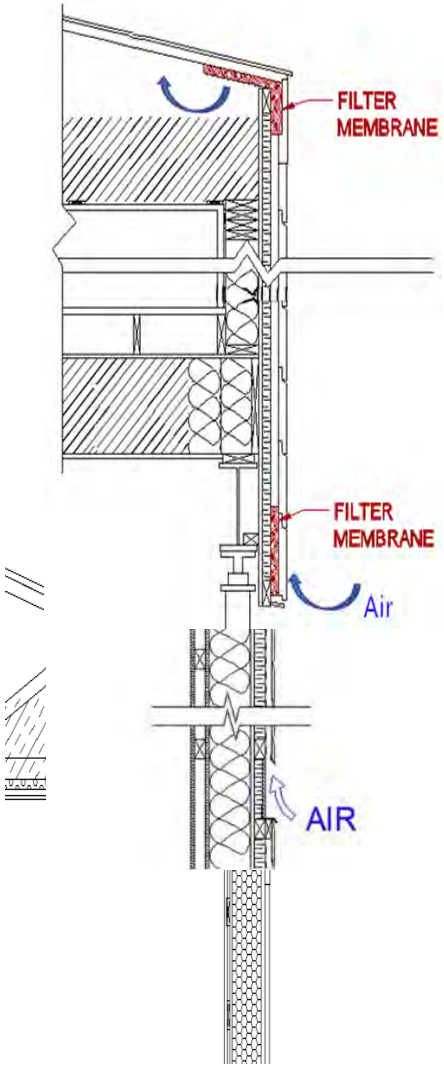
- Location: Kuujjuaq (2012)
- Style: Single-Story Duplex House
- Attic Construction: Ventilated Attic (with two filter membrane)

House II

- Location: Kuujjuaq (2008)
- Style: Two-Story Duplex House
- Attic Construction: Ventilated Attic (with one filter membrane)

House III

- Location: Iqaluit (2012)
- Style: Two-Story Duplex House
- Attic Construction: Unventilated Attic



2. Experimental Setup

➢ Remote Hygrothermal Performance Monitoring System

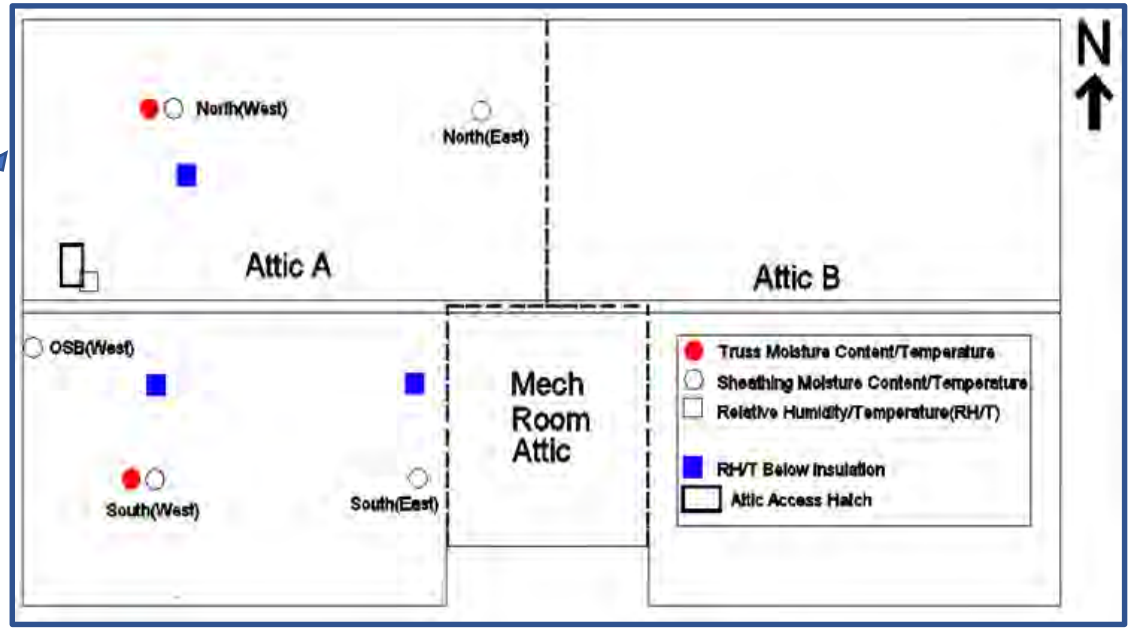
Wireless data acquisition system

- **Relative humidity and temperature (RH/T)** of air in attic spaces, indoors and outdoors
- **Moisture content (MC)** of plywood sheathing and trusses measured
- Data collected by internet connected laptop located in the building's mechanical room

2. Experimental Setup

➢ Sensor Location

House I



Summary of Sensors
✓ 5 Sheathing MC/T Sensor
✓ 2 Truss MC/T Sensor
✓ 1 RH/T Sensor above attic access hatch
✓ 3 RH/T below insulation

2. Experimental Setup

- Site observation

House I

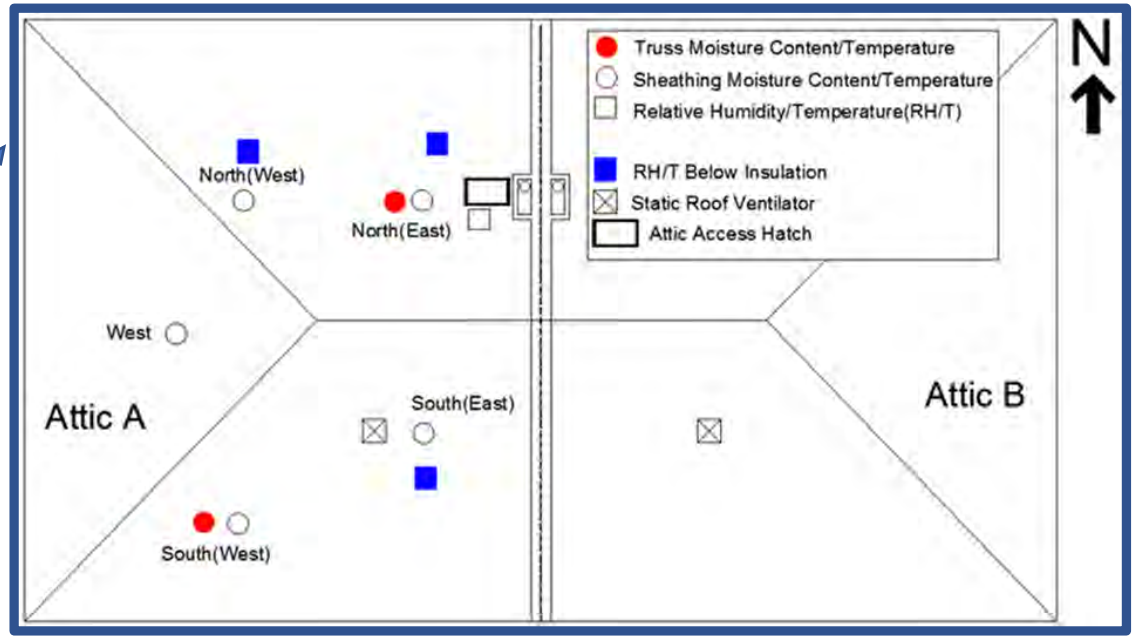
No Signs of Moisture on Building Materials and Roofing Nails not Rusted

Dead Bolt Locks Installed to Ensure Hatch Pulled Tight onto Weather Stripping

2. Experimental Setup

➢ Sensor Location

House II



Summary of Sensors
✓ 5 Sheathing MC/T Sensor
✓ 2 Truss MC/T Sensor
✓ 1 RH/T Sensor above attic access hatch
✓ 3 RH/T below insulation

2. Experimental Setup

- Site observation

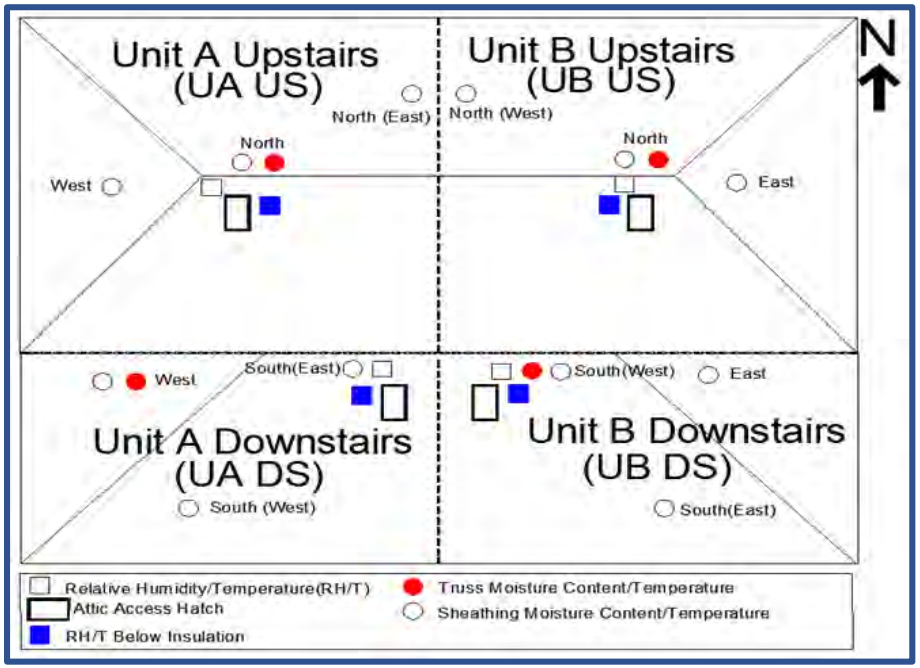
House II

No Signs of Moisture on Building Materials and Roofing Nails not Rusted

2. Experimental Setup

➢ Sensor Location

House III



Summary of Sensors
✓ 12 Sheathing MC/T Sensor
✓ 4 Truss MC/T Sensor
✓ 4 RH/T Sensor above attic access hatch
✓ 4 RH/T below insulation

2. Experimental Setup

➢ Site observation

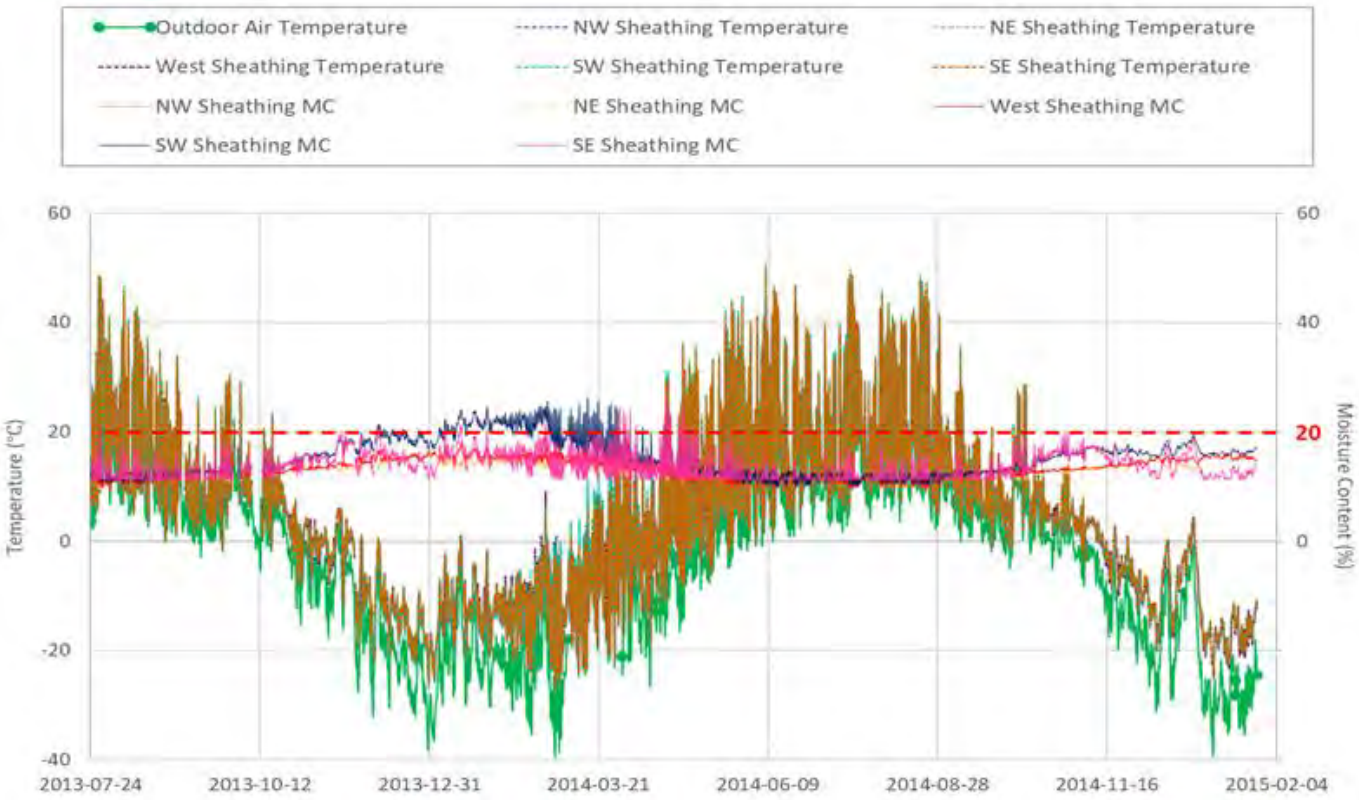
House III

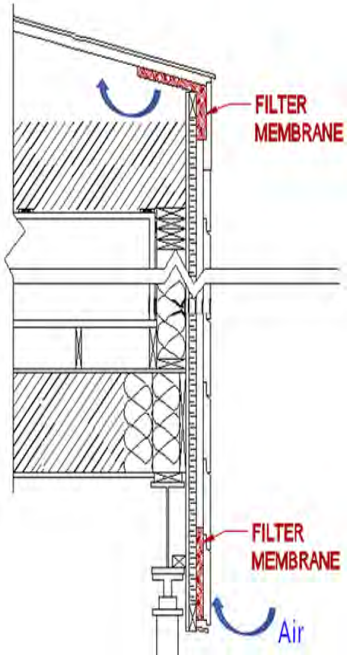
Wet Plywood Sheathing

Rusty Nails and Black Spot on Truss

3. Results and Discussion

- House I (ventilated attic with filter membrane at two locations)

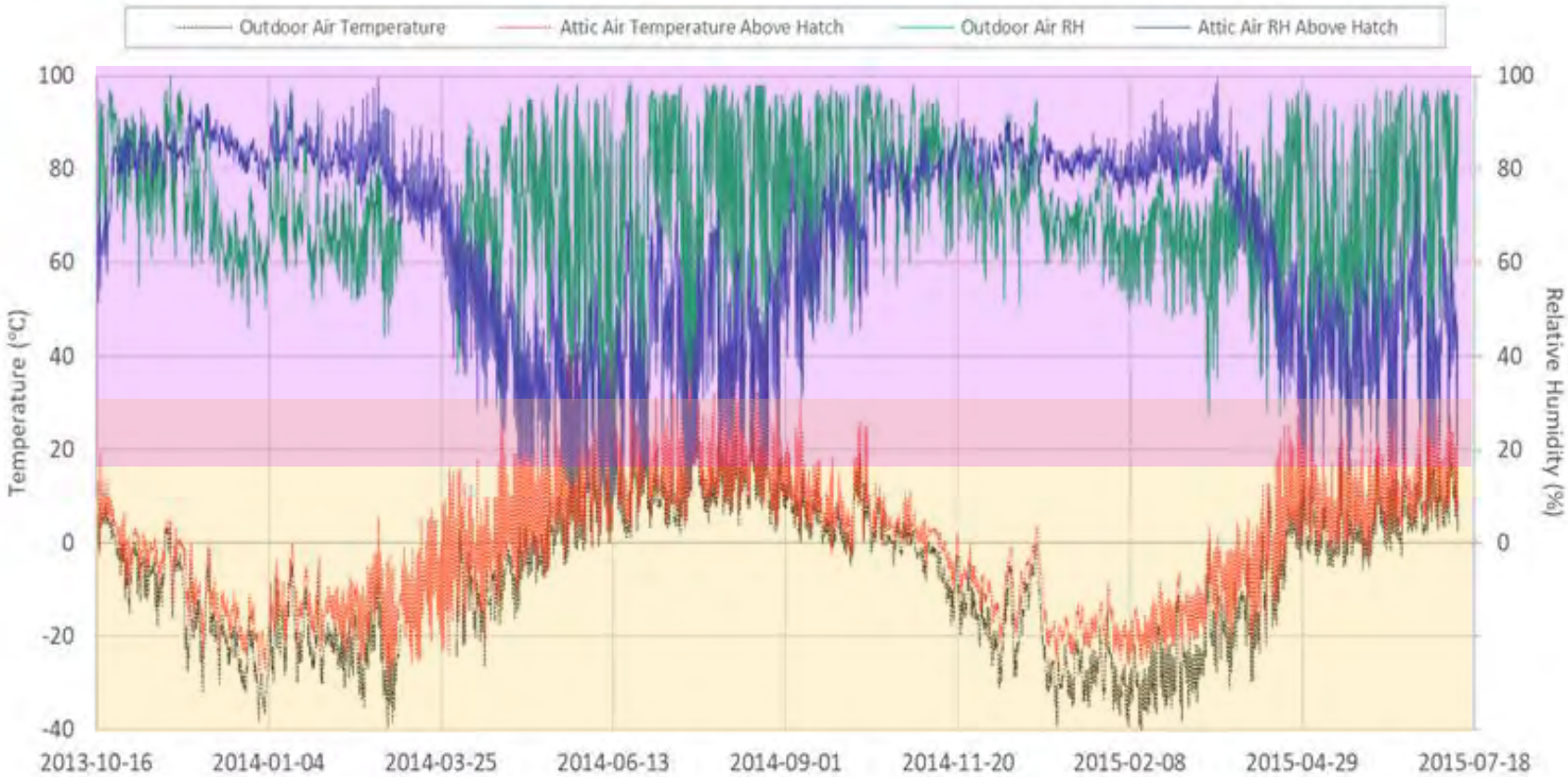




Moisture Content and Temperature of Plywood Sheathing in House I Measured During the Monitoring Period from July 2013 to January 2015

3. Results and Discussion

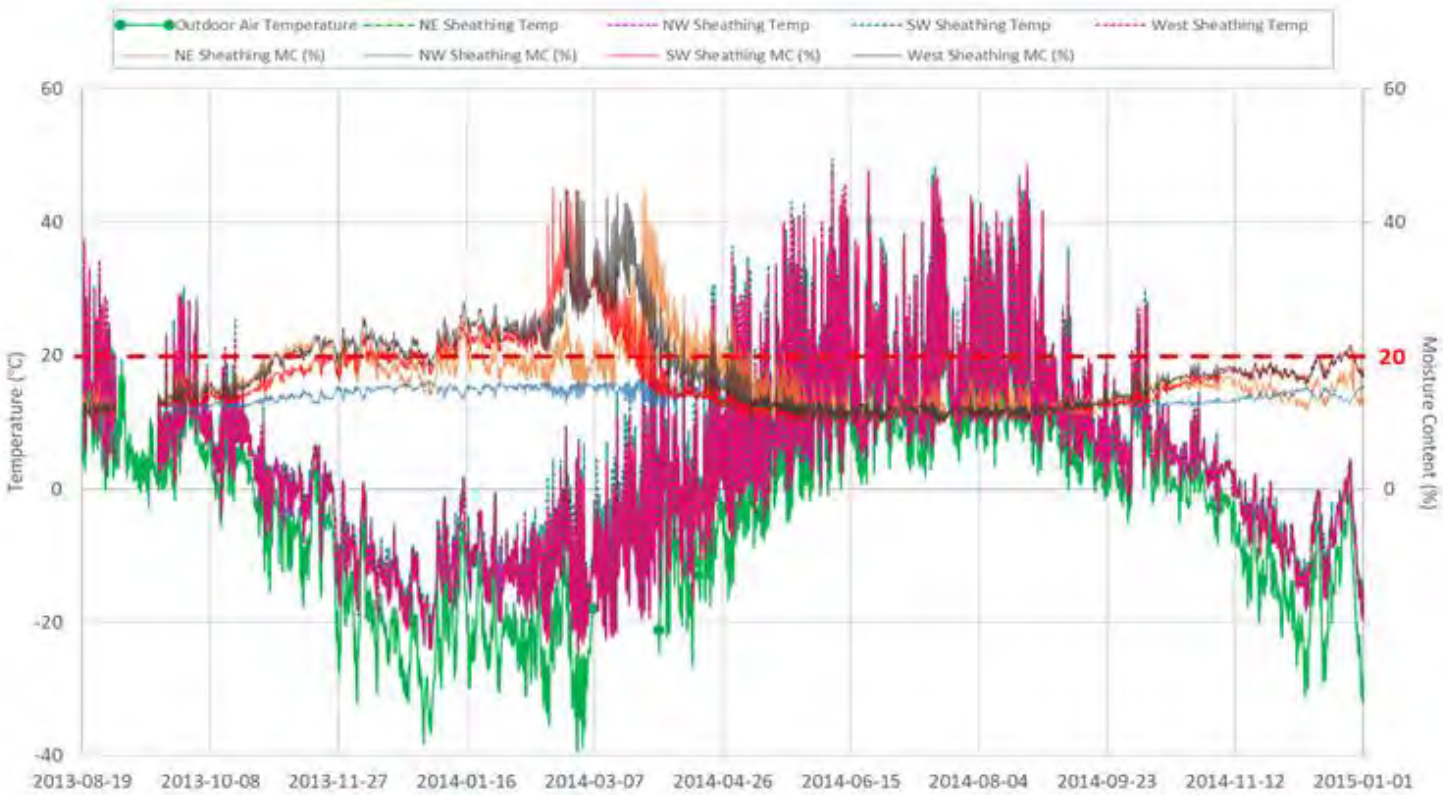
- House I (ventilated attic with filter membrane at two locations)

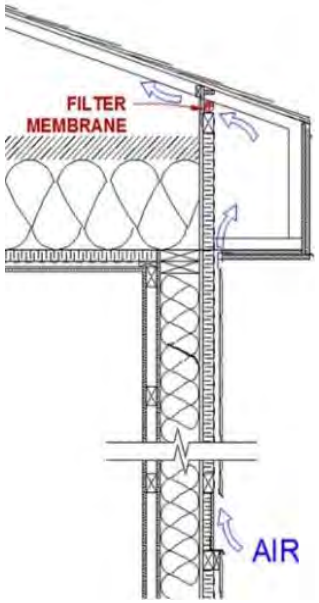


Attic Air RH/T Compared to Outdoor Air RH/T Measured During the Monitoring Period from October 2013 to July 2015

3. Results and Discussion

- House II (ventilated attic with filter membrane at attic entrance)

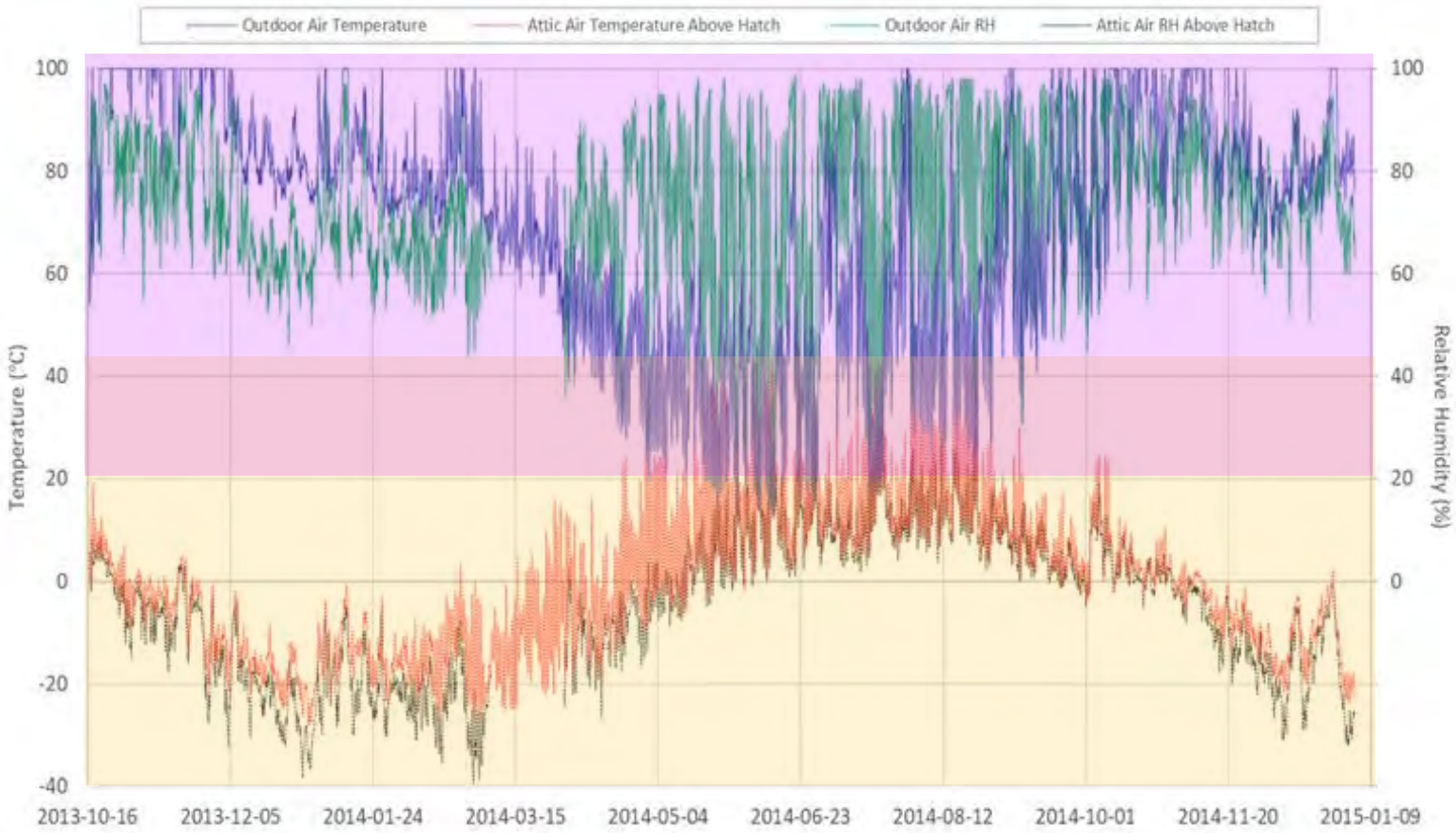




Moisture Content and Temperature of Plywood Sheathing in House II Measured During the Monitoring Period from August 2013 to January 2015

3. Results and Discussion

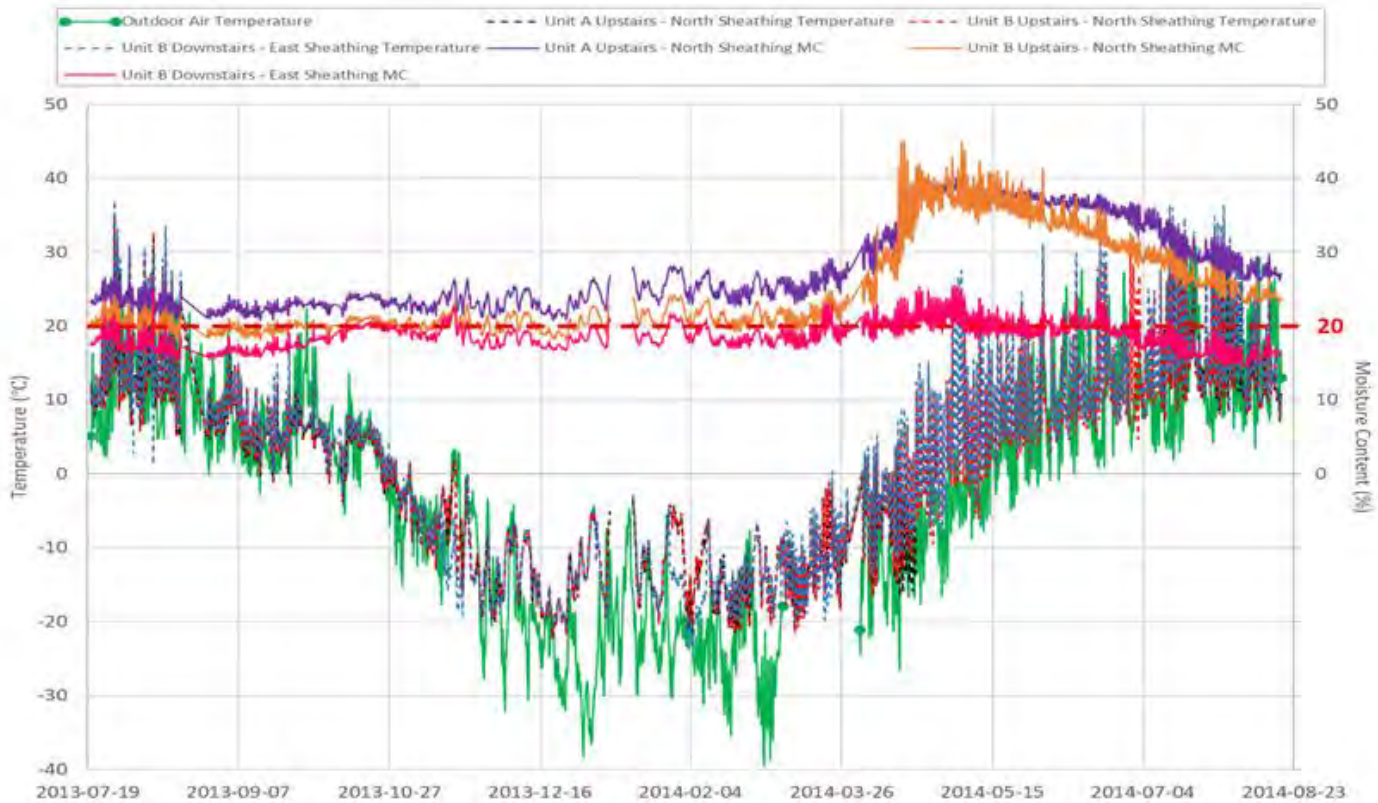
- House II (ventilated attic with filter membrane at attic entrance)

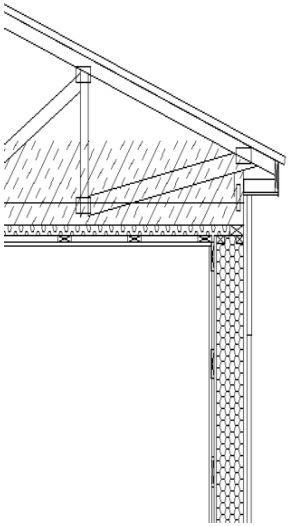


Attic Air RH/T Compared to Outdoor Air RH/T Measured During the Monitoring Period from October 2013 to January 2015

3. Results and Discussion

- House III (un-ventilated attic)

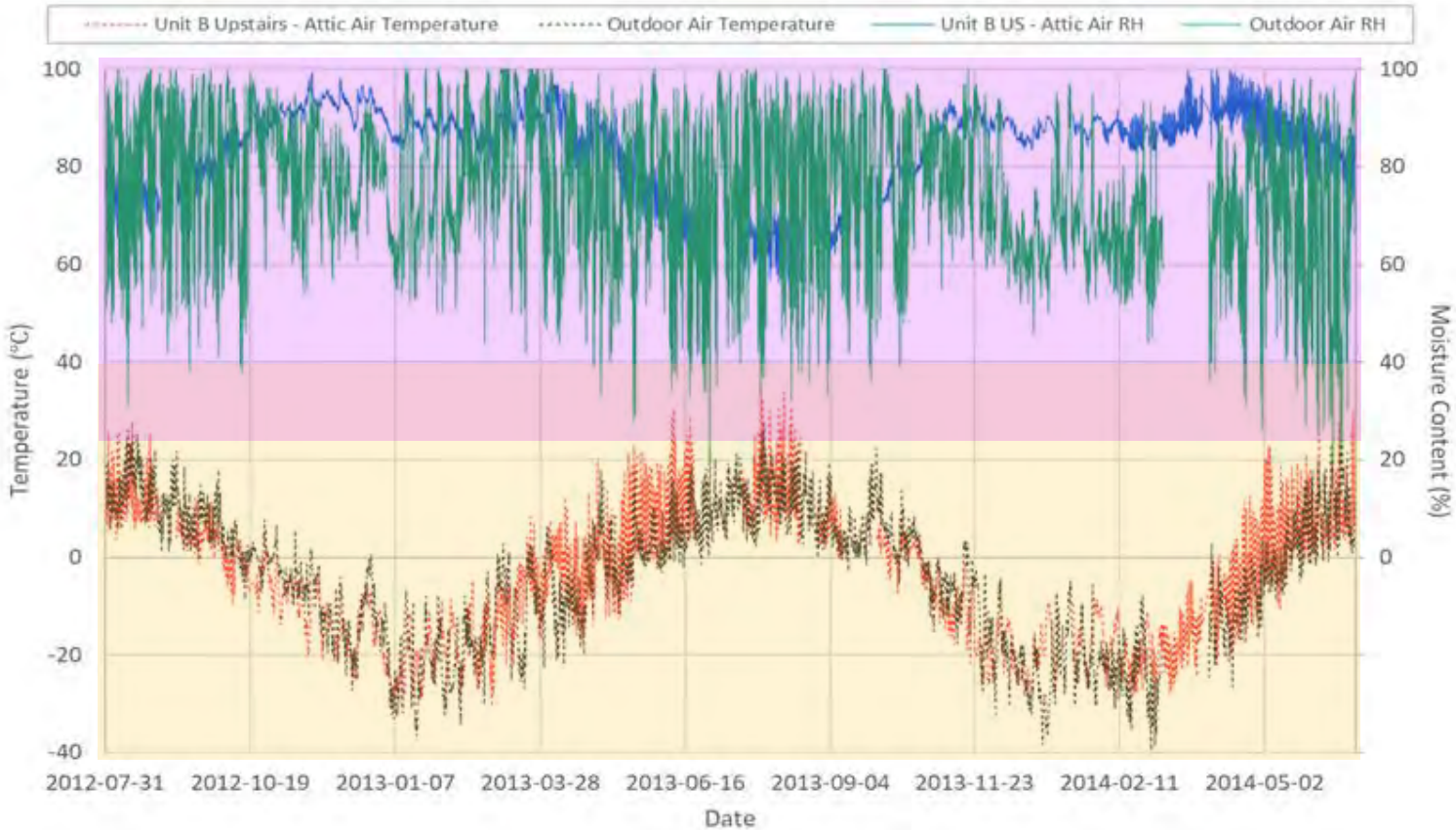




Moisture Content and Temperature of Plywood Sheathing Measured During the Monitoring Period from July 2013 to August 2014

3. Results and Discussion

- House III (un-ventilated attic)



Attic Air RH/T in Unit B Upstairs Compared to Outdoor Air RH/T Measured During the Monitoring Period from August 2012 to June 2014

3. Results and Discussion

- Comparison of Three Venting Systems

	RH (Attic air)	ΔT (attic air-outdoor air)
House I	Average: 65.2% Min: 8.8% Max: 99.5%	Average (+): 8.4 ºC Average (-):-3.2 ºC Min: -22.5 ºC Max: 37.9 ºC
House II	Average: 69.9% Min: 12.4% Max: 100%	Average (+): 5.4 ºC Average (-):-2.9 ºC Min: -13.7 ºC Max: 35 ºC
House III	Average: 75% Min: 55% Max: 100%	Average (+) 5.9 ºC Average (-):-5.2 ºC Min: -18 ºC Max: 23 ºC

3. Results and Discussion

Comparison of Three Venting Systems

	MC of plywood sheathing
House I	**NW, NE, W:** below 16% throughout the year **SE and SW:** above 20% from Jan. to March, peaked at 25% in Feb., dried to 10% during the summer months.
House II	**NW:** 10-15% throughout the year **SW, W:** peaked over 40%, dried to below 20% by end of March, dried to 11% during summer **NW:** peaked over 40%, dried to below 20% by end of April, dried to 11% during summer
House III	**Unit A N:** initial MC of 23%, slight increase during winter, abrupt increase at end of March, peaked over 40%, remained high level till June and slowly dried to 27% at the end of Aug. **Unit B N:** initial MC of 20%, slight increase during winter, abrupt increase at end of March, peaked over 40%, remained high level till June and slowly dried to 25% at the end of Aug. **Unit B E:** initial MC of 18%, slight increase over winter time, above 20% from March to June, dried to about 18% at end of Aug.

4. Conclusions

- **In general, the ventilated attics with filtering membrane managed to maintain attics at acceptable conditions :**
  - House I performs slightly better than House II
  - MC in plywood sheathing of House II reached high level during spring time but be able to dry to 10% during the summer

- **For the un-ventilated attic :**
  - Sheathing moisture content levels remained above 25% through the summer
  - Sheathing MC higher than initial at the end of the first summer
  - Without ventilation the initial built-in construction moisture and moisture accumulated through winter-time cannot be effectively removed

4. Conclusions

➢ Future work

- Further investigation of long term performance with seasonal MC variations in ventilated attic is needed

- Further investigation of the appropriateness of unventilated attic under extreme cold climates through continued field monitoring and modeling is required

Acknowledgement

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Thank you!

Questions?