Monitoring of Unvented Roofs with Diffusion Vents & Interior Vapor Control in a Cold Climate

Building Science Corporation
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Project Summary

Timeline:

Start date:October 2016

Planned end date: September 2019

Key Milestones

1. Budget Period 2→3 Go/No-Go (October 2018)
2. Milestone 8.1 Winter 2 Report (January 2019)
3. Winter 3 Air Leakage System (February 2019)

Key Partners:

DowDuPont	NAIMA
Owens Corning	Nu-Wool
Cosella-Dörken	

Budget:

Total Project $ to Date: $355,647

- DOE: $279,687
- Cost Share: $75,960

Total Project $: $544,687

- DOE: $429,687
- Cost Share: $115,000

Project Outcome:

In an effort to improve moisture-managed high-R envelopes to reduce heating and cooling loads, the moisture safety of roofs insulated with fibrous insulation in cold climates is being monitored. This early-stage research will provide more options for lower-cost unvented roofs, thus increasing market penetration. At 5% of new single-family housing start, this would be on the order of 40,000 units/year.

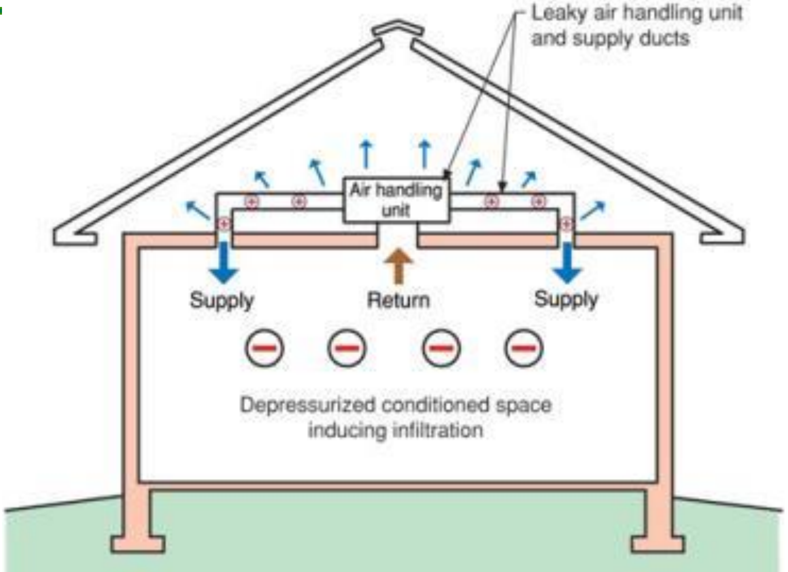
Team

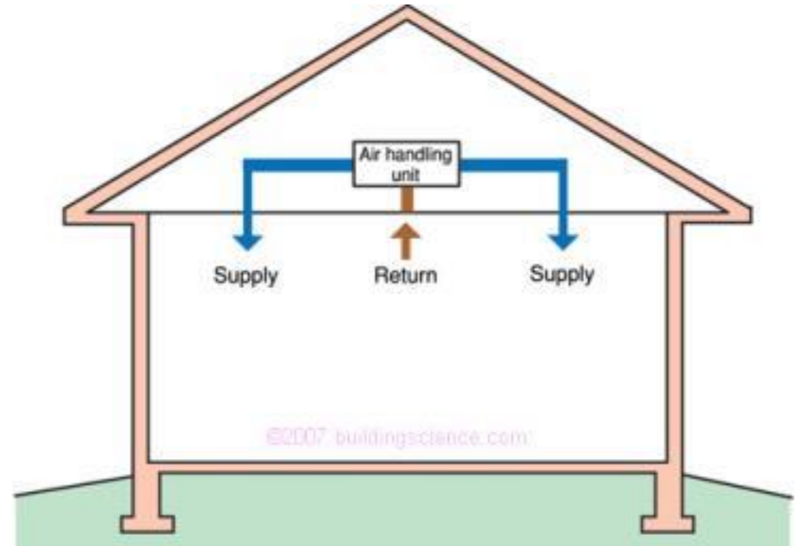
OFFICIAL TEAM MEMBERS	
DowDuPont	NAIMA
Owens Corning	Nu-Wool
Cosella-Dörken	

ADVISORY TEAM MEMBERS	
Johns Manville	Knauf
Saint-Gobain	Rockwool

- Project team includes leading building material manufacturers and industry trade associations.
- Advisory team includes further insulation manufacturers/industry leaders
- Team provides cost-share funding, project input/vetting, connection to market opportunities, and donations of key building materials/installation
- Annual on-site meetings to discuss project results (August 2017, August 2018)

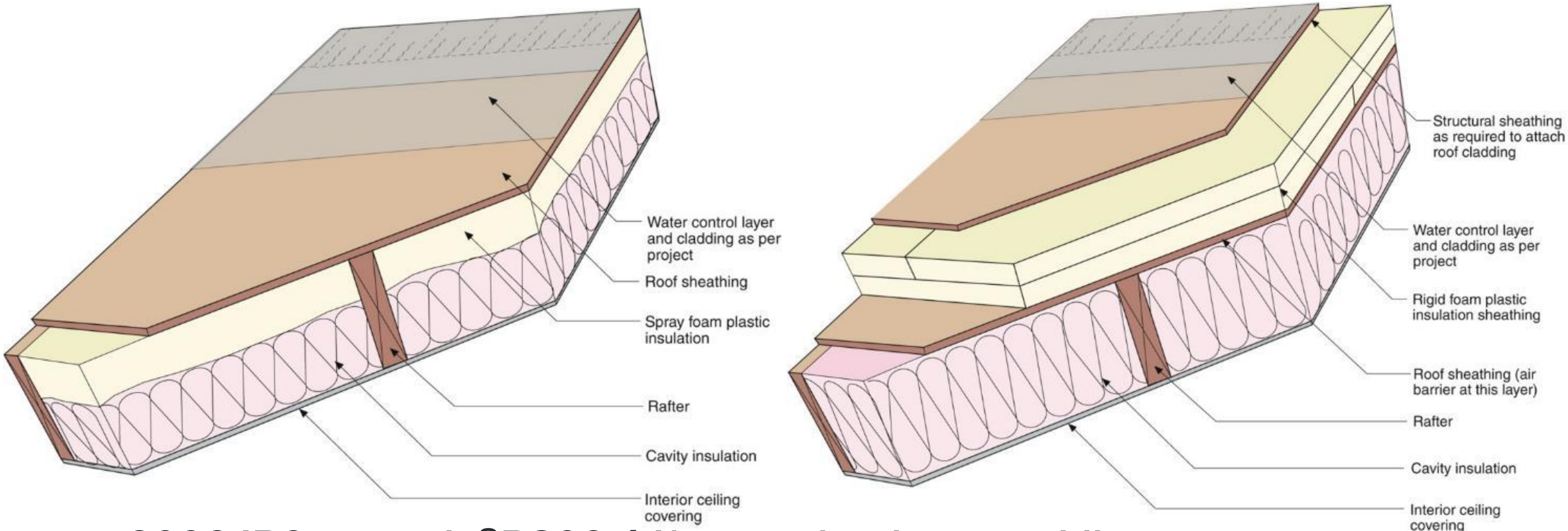
Challenge: Energy Loss in Unconditioned Attics





- **Ducts in unconditioned attic = substantial energy losses**
  – Industry reluctant to move ducts out of attic
- **Solution: bring ducts into conditioned space**
- **Unvented/conditioned attic**
  – Keeps ductwork in conditioned space, duct leak issues eliminated
  – “Unventable” roof configurations (cathedrals, complex geometries)
  – Lowers risks for hot-humid climates (ductwork and AHU condensation)
  – Potential airtightness improvement

Challenge: Moisture Control in Unvented Roofs



- **2006 IRC onward: §R806.4 Unvented attic assemblies**
  - Minimum R-value of "air impermeable insulation" (foam), controls wintertime condensation risks
- **High cost of spray foam or rigid foam + nail base**
- **Anti-foam sentiment in industry segments**
- **Unvented roofs with fibrous insulation alone**
  - Lower cost option but moisture risks; topic of research

Challenge

Problem Definition:

- **Moisture-safe unvented roofs (spray foam, exterior rigid foam): code-compliant, effective, but costly with limited uptake**
- **Insulating roofs with fibrous insulation only: some research exists, but no systematic study with current vapor control and drying technologies**
  - Assembly considered risky: quantifying risks
- **Research aligns with the DOE goal of developing Moisture Managed High-R Envelopes**
- **Cautious approach:**
  - High moisture risk assemblies = moisture failures
  - Damages reputation of technique & hurts energy efficiency efforts
- **Targeting climate zones at least up to 5A**

Approach

Approach:

- Climate Zone 5A Test Hut: side-by-side test roofs constructed and monitored for moisture behavior over 3 winters
- Using "diffusion vents": vapor open but air leakage closed detail at ridge to release accumulated moisture

Key Issues:

- Constructability of fibrous insulation at roofline/unvented
- Costs vs. current practice—estimated cost reduction from current SPF roof factor 2-3 typical
- Moisture measured by mold index model (from T-RH data)
- Visual inspection of roof bay conditions (summer disassembly)

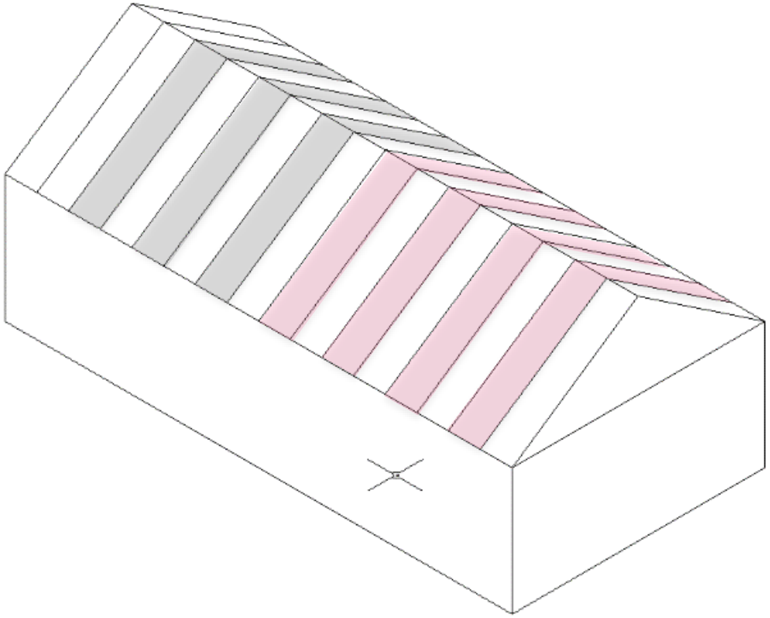
Distinctive Characteristics:

- Side-by-side assembly and north/south test hut approach
- Cooperation from manufacturers in multiple insulation industries; DOE providing third party unbiased research

Test Hut Experimental Approach

- **Climate Zone 5A test hut**
- **Eight north-south roof bays**
- **±R-50 (14-¾" framing, 2012 IECC)**
- **Test variables (changed Winters 1/2/3):**
  - Vapor retarder: fixed perm, variable perm (several diffusion curves)
  - Diffusion vent at ridge, no diffusion vent, DV size, DV permeance
  - Fiberglass vs. cellulose
  - "Control" comparison §R806.4 spray foam + cellulose
- **Varying interior boundary conditions**
  - Winter 1: "Normal" interior conditions (constant T, ~30% RH)
  - Winter 2: Elevated RH (50% constant)
  - Winter 3: Air leakage into rafter bays

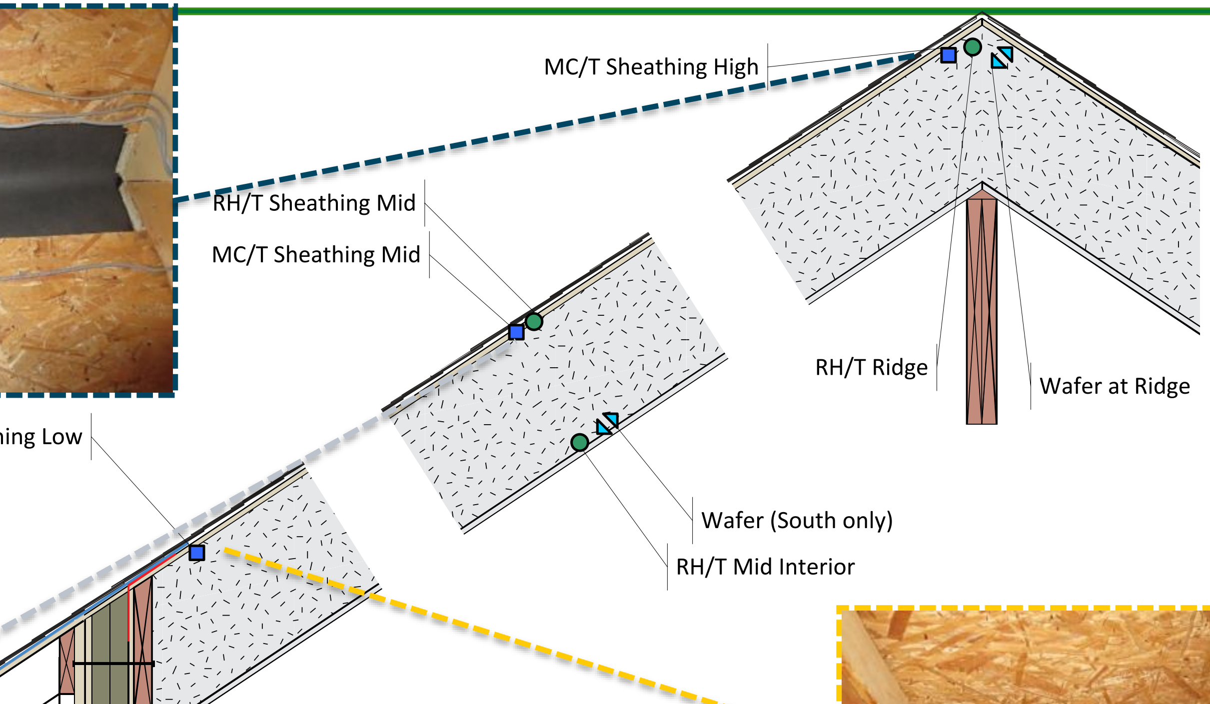
Test Hut South Elevation



Experimental Approach: Diffusion Vent

- Previous research: moisture concentrates at roof ridge
- Release water vapor via vapor-permeable watertight membrane (~500 perms)
- Previous installations & monitoring in CZ 2A (Houston, Orlando)

Experimental Approach: Instrumentation



Notes

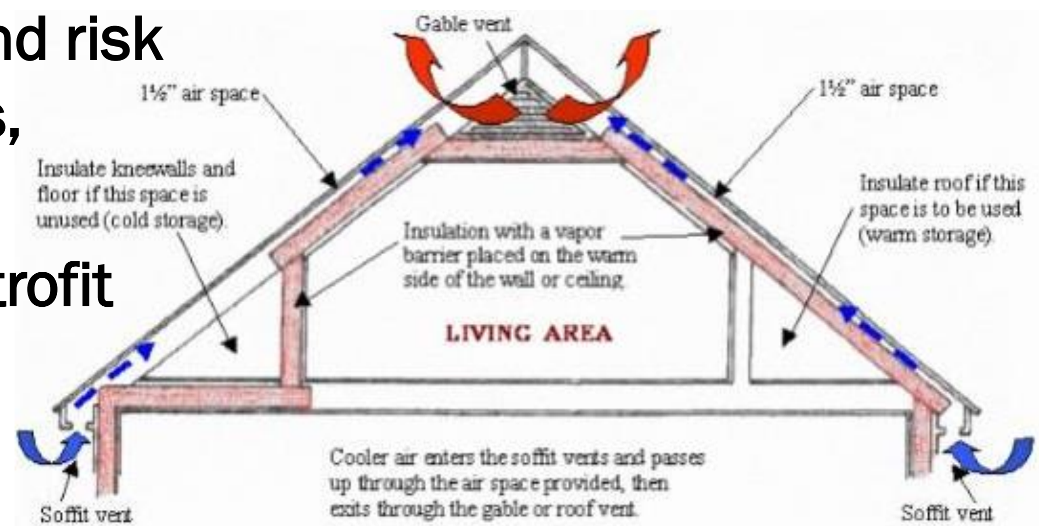
- "MC/T Sheathing High" is at top edge of sheathing at diffusion vent, or equivalent location in non-DV roofs
- Wafer and RH/T at ridge are directly under ridge

Sensor Key:

- ▲ Temperature
- ● Relative humidity/temperature
- ■ Moisture content/temperature
- ⧅ Moisture content block

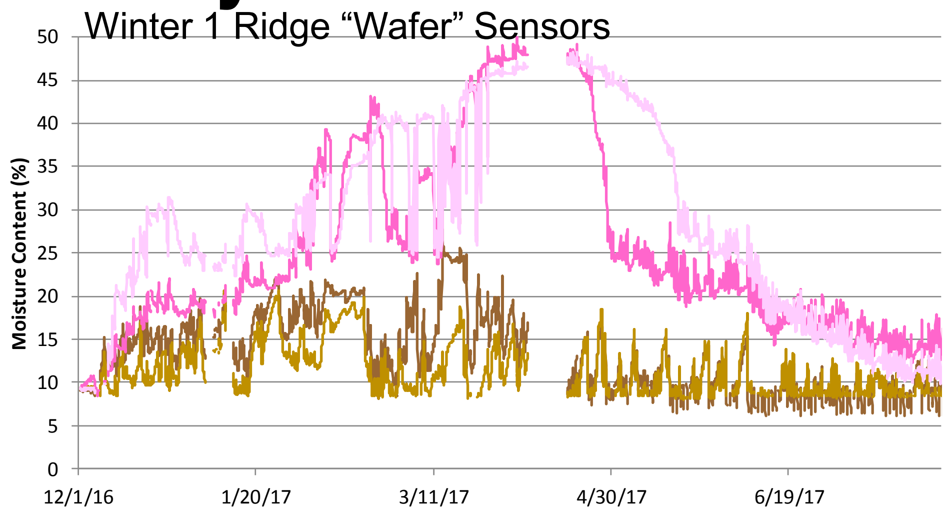
Impact

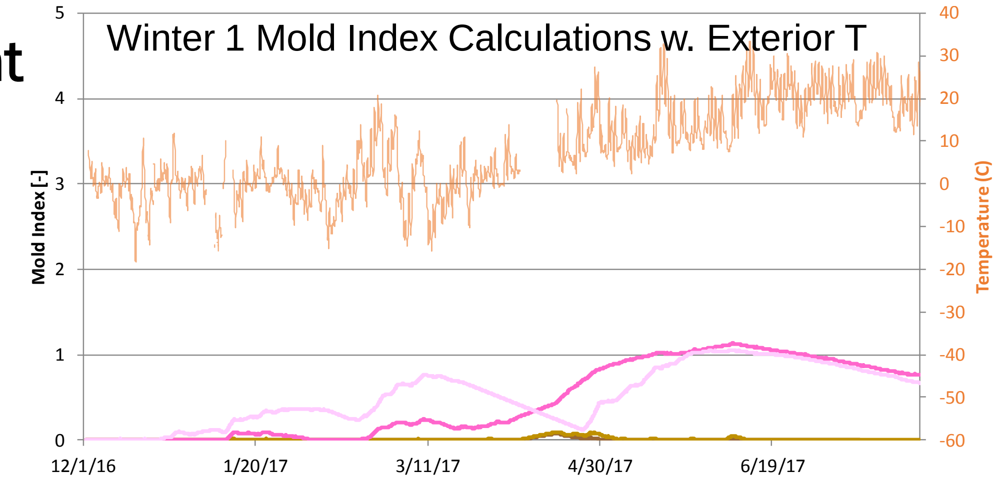
- Potential for higher-R roofs (meeting 2012 IECC) insulated at roofline; ducts within conditioned space; greater airtightness, at lower costs than current practice
- Lower costs → wider deployment
- Knowledge from research informs potential moisture risks of all-fibrous insulation, and risk factors (interior conditions, orientation, roof location)
- Potential application in retrofit geometries (kneewall, short cathedral ceiling)



Progress: Winter 1 Takeaways

- "Normal" interior RH
- High moisture concentrated at roof ridges (gradient), north worse than south
- Non-diffusion vent (nDV) roofs show wintertime condensation, high sheathing moisture content (vs. diffusion vent roofs)
- Variable-perm ("smart") vapor retarder + DV safest combination
- All roofs pass ASHRAE 160 (MI)
- Fiberglass & cellulose similar
- Inward drive with fixed-perm VR





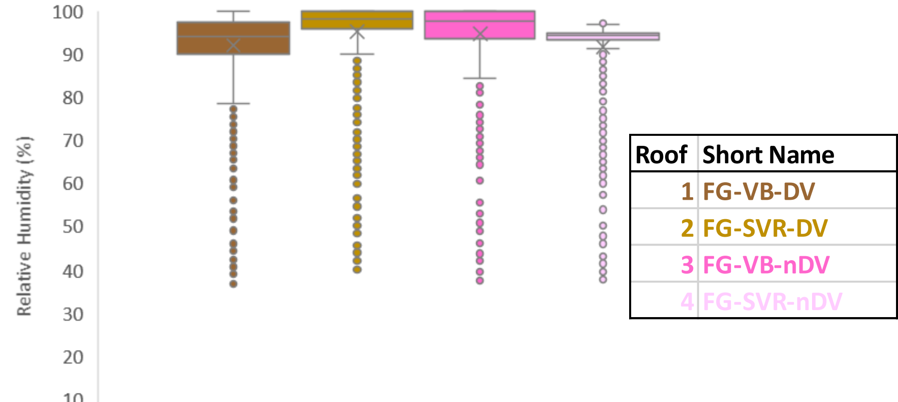
Roof	Name	Diff. Vent	Vapor Retarder
1	FG-VB-DV	DV Roofs	1 Perm Fixed
2	FG-SVR-DV		Variable Perm
3	FG-VB-nDV	No DV Roofs	1 Perm Fixed
4	FG-SVR-nDV		Variable Perm

Progress: Winter 1 → Winter 2 Changes

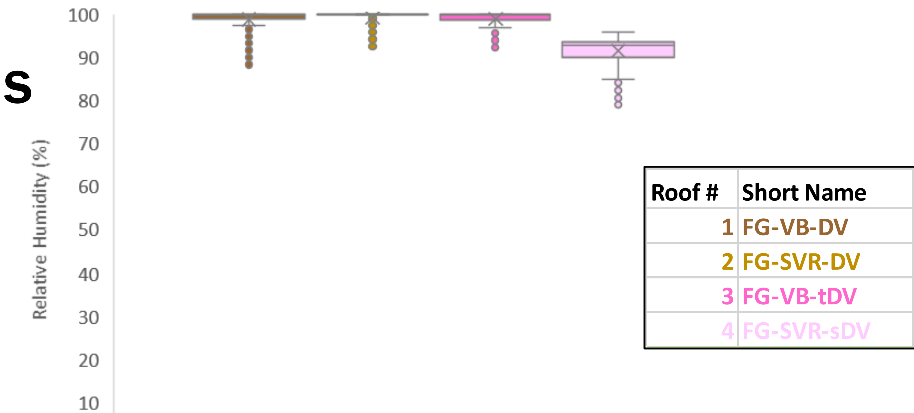
- Replace poor performers from Winter 1
- Non-DV roofs changed with "small" and "tight" DVs
- Cellulose settling, especially on north side (full length of bay)
- Moisture evidence at nDV roofs
- Add humidification (50%)

Progress: Winter 2 Takeaways

- 50% "flatline" interior RH
- Roofs with diffusion vent & variable-perm VR safest, BUT
- 50% RH→ much more challenging; many roofs at risk of failure
- "Tight" diffusion vent (25 perms vs. 500 perms) did not work acceptably
- "Small" diffusion vent: better than nothing, but larger allows more drying
- All roofs pass ASHRAE 160 (MI)



Winter 1 North RHs @ sheathing



Winter 2 North RHs @ sheathing

Progress: Winter 2 → Winter 3 Changes

- "Tight" DVs to full size DVs
- New interior vapor control membrane
- Ridge disassembly (replace failed sensors)
- Mold growth occurring at roof ridges (despite ASHRAE 160)
- Repack all settled roof bays

Progress: Takeaways from Data to Date

- Unvented roof assemblies with fibrous insulation and interior vapor control can work
- Diffusion vent + variable-perm vapor retarder safest
- But at higher interior RHs, roofs accumulate moisture, in the risk range
- Disassembly revealed mold growth on sheathing & framing
- Airtightness of interior vapor control critical for performance → testing requirements
- Impossible to guarantee interior wintertime RH control (operation of ventilation system, tighter buildings)
- Difficult to recommend technology as-is for wide deployment (too many caveats/conditions)
- Code-compliant spray foam (§R806.5) roof safest by far

Stakeholder Engagement

- Annual meetings with team members (August 2017, August 2018) plus report updates
- Building insulation and building material manufacturers represented
- Research project presented at conferences (NESEA BE19, Passive House US, Buildings XIV)
- Consulting with residential and commercial building industry on implementing diffusion vent roofs (small scale deployments, retrofits)

Remaining Project Work

- Final winter of operation 2018-2019 (air injection) & 50% RH
- Continue data collection, observe summer dry-down
- Decommission and disassemble: sheathing conditions, airflow pathways in insulation?
- Final data analysis and recommendations
- Share results/recommendations with industry stakeholders
- Future research: limited retrofit applications?

Thank You

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REFERENCE SLIDES

Project Budget

Project Budget: Three-year project, covering monitoring of climate zone 5A test hut
Variances: n/a
Cost to Date: Roughly 65% of total budget spent to date
Additional Funding: Cost share provided by funding partners (Nu-Wool and NAIMA)

Budget History					
October 2016 – FY 2018 (past)		FY 2019 (current)		FY 2020 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$258,331	$68,960	$ 171,355	$46,039	n/a	n/a

Project Plan and Schedule

- Start date: October 2016
- Planned end date: September 2019
- Three Winters of Operation
  - 2016-2017: Winter 1 (“Normal”)
  - 2017-2018: Winter 2 (“Humidified”)
  - 2018-2019: Winter 3 (“Air Leak”)
- Go/no-go decision: viable assemblies based on roof moisture? (Mold Index)

- Current work:
  - Finishing Winter 3 data collection
  - Winter 3 start: no air leakage (“baseline operation”)
  - Air leakage system in operation
- Future work:
  - Summer dry-down
  - Disassembly & decommissioning

ID	Task *Blue = Design/Implementation* *Green = Reporting*	Start	Finish
1	Roof Assembly Selection	10/20/2016	11/17/2016
2	Vetting Test House, Site Visit	11/3/2016	12/1/2016
3	Roof Instrumentation Package Design	12/5/2016	1/2/2017
4	Instrumentation Setup & Testing	1/3/2017	1/20/2017
5	Test Plan to Industry Partners	1/3/2017	2/2/2017
6	Pre-Insulation Instrumentation (“Rough”)	1/23/2017	2/6/2017
7	Insulation/Installation Documentation	2/7/2017	2/22/2017
8	Post-Insulation Instrumentation (“Final”)	2/7/2017	2/21/2017
9	Field Testing/Commissioning	2/8/2016	2/22/2016
10	Reporting: Instrumentation & Testing	3/22/2017	4/6/2017
11	Reporting: Initial Data (Sensor Function)	5/8/2017	5/22/2017
12	Reporting: Winter 1 Results	8/22/2017	9/18/2017
13	Develop and Test Humidification System	10/23/2017	11/21/2017
14	Install Humidification System	12/21/2017	1/4/2018
15	Reporting: Winter 2 Results, Humidifier	8/22/2018	9/17/2018
16	Develop and Test Air Leak System	9/20/2018	10/18/2018
17	Install Air Leak System	12/24/2018	1/8/2019
18	Decommissioning and Disassmbly	8/21/2019	9/3/2019
19	Reporting: Winter 3 Results, Air Leakage	8/21/2019	9/16/2019
20	Reporting: Final and Summary	9/18/2019	10/16/2019