High Performance Attics for Zero Energy Homes

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New Approach to Sealed and Insulated Attics

Fibrous insulation vs. spray-foam

- Increased insulation, R38 vs. R20
- ~40% lower cost
- Familiar to contractors
- Lower Health / IAQ risks
- Increased moisture risk?

Key Questions

1. Do fibrous insulation approaches result in a sealed and insulated attic that can be considered thermally within conditioned space with consummate energy savings?

2. Does moisture and air permeable insulation used in new California homes lead to increased moisture risk or definite moisture problems in the state's climate regions?

Study Approach

- Literature review
- Field testing in two new homes in Fresno and Clovis
- Simulations to investigate moisture mitigation approaches

Code Requirements for Vapor-permeable Insulation

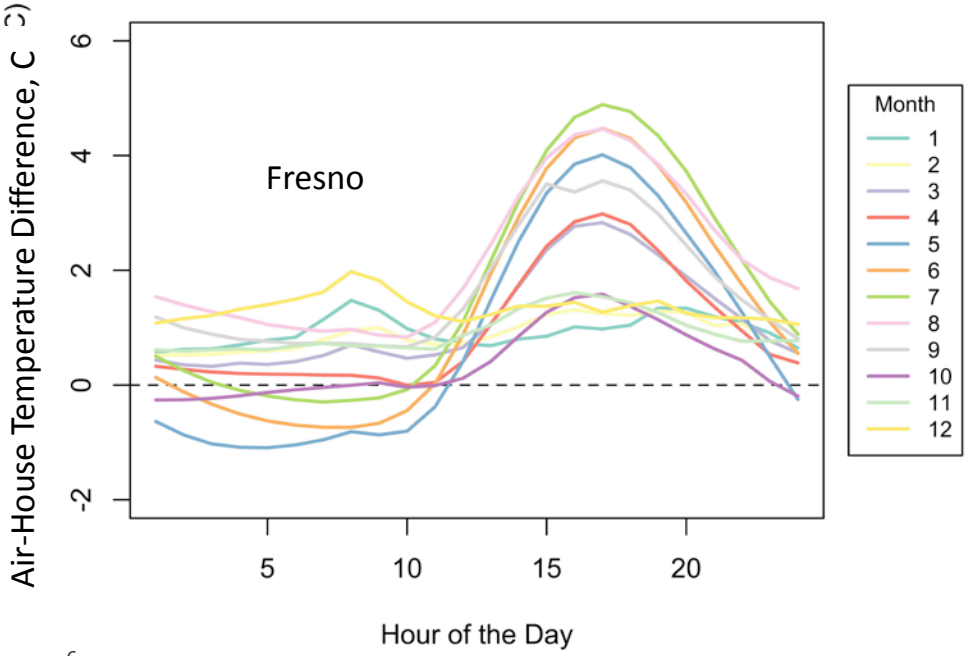
- Table 806.5 2012 IRC and the 2016 California Residential Code Section R806.5: Insulation requirements for insulation above roof sheathing ***to prevent condensation***
- Supply register in attic

U.S. DOE Climate Zone	CEC Climate Zone	Minimum Air Impermeable Insulation R-Value	2012 IECC Required Total R-Value	CEC Required Total R-value
2B and 3B tile roof only	6-15 tile roof only	0	30	32 - 40
1, 2A, 2B, 3A-C	3-15	5	38	32 - 40

Thermal Performance

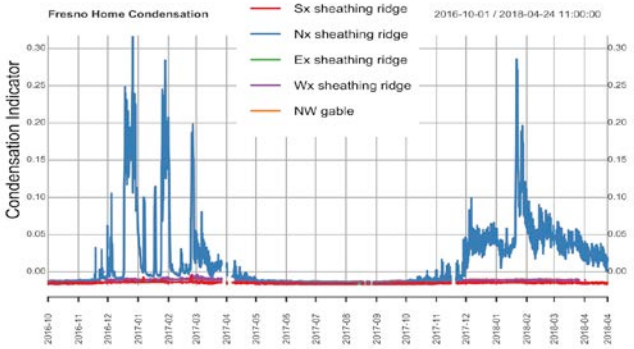
- Historic spray foam applications:
  - Some attics insufficiently insulated
    - Often R20 insulation – should be at least same as ceiling requirements
    - Need R48 on 5:12 + gables to match an R38 flat ceiling
  - Attics need to be at least as tight as the home
- Field study:
  - Fresno: 0.1 and 0.7 C warmer than home
  - Clovis: 1.7 C warmer than home
  - Close enough to indoors to get good HVAC performance
  - Attic air warmer at peak and stratified on summer days
  - N-S peak roofs much bigger variation than E-W peak roofs

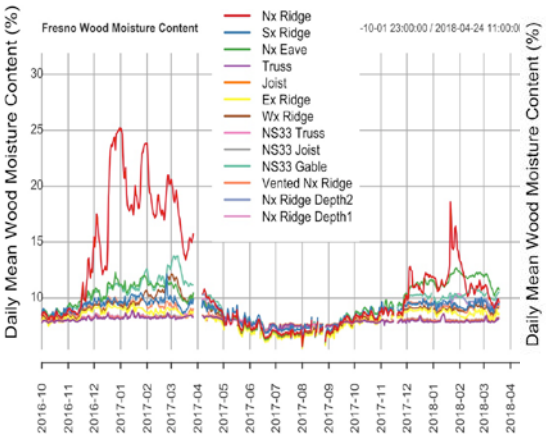
Solar driven: bigger in summer and in afternoons

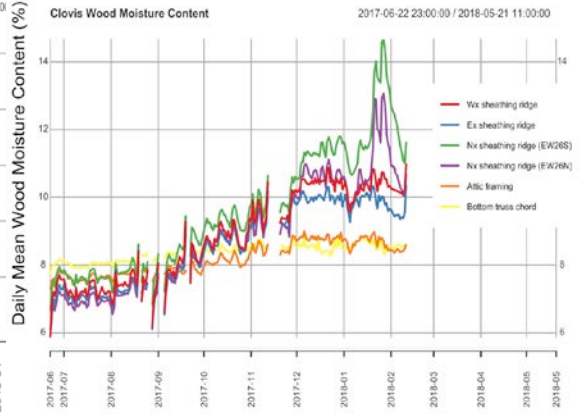


Moisture Performance

- Historic spray foam applications:
  - Generally attics are more humid than homes – moisture stored and released in wood
  - Severest moisture problems occur during cold weather and cold climates
  - Most moisture problems at the attic peak
- Field study:
  - Risk is the North orientation at the peak in winter
  - Stratification does not explain results
  - Condensation was present for 20% of annual hours on the North-oriented roof sheathing in Fresno
  - **Surface** Wood Moisture Content low in Clovis and below level for rot/decay in Fresno

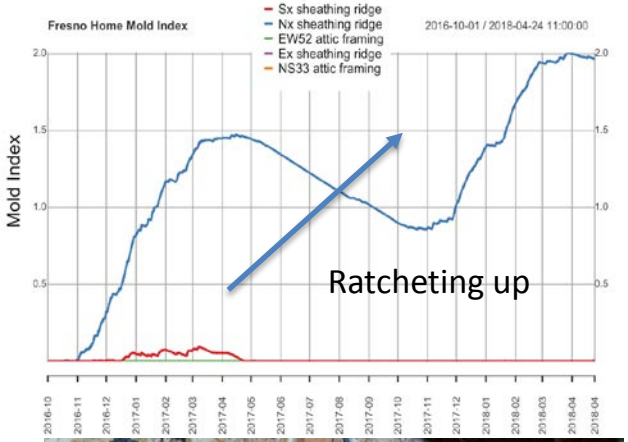


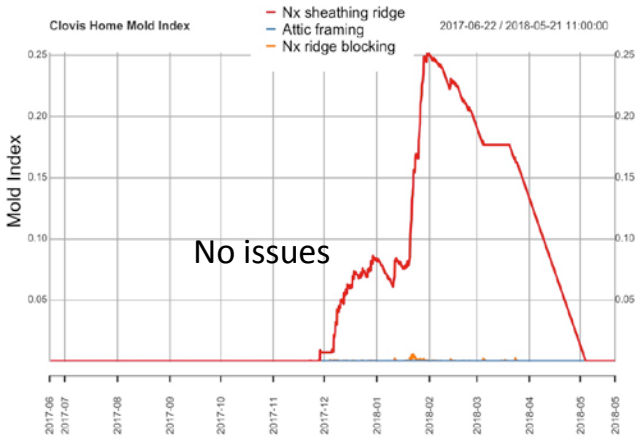




Moisture Performance - Mold

- Field study:
  - ASHRAE 160 Mold Index below 3
    - OK in Clovis
    - Maybe OK in Fresno
  - Observations:
    - No issues in Fresno
    - Suspected mold in Clovis

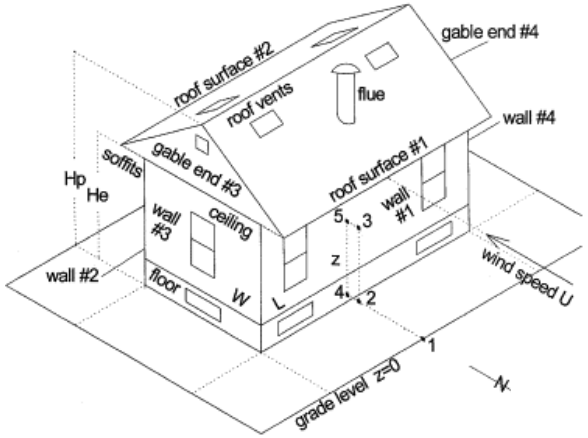


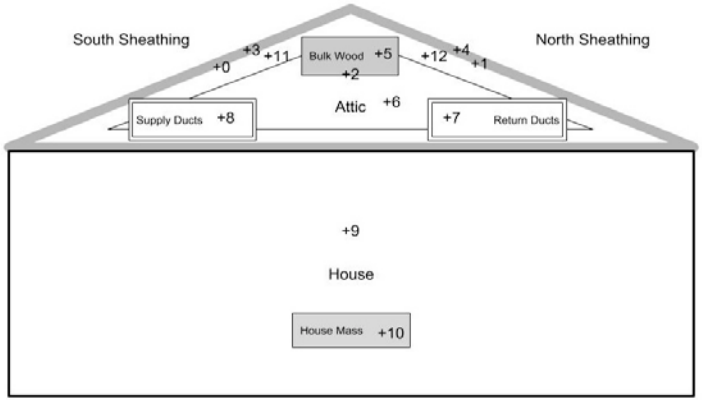


Mold on north-facing roof deck in Fresno home

Simulations of Attic Performance

- Combined heat, air and moisture transport + HVAC
- Minute-by-minute
- 4 year sims
- CEC T24 prototype homes
- Range of attic & house leakage
- All 16 CZs





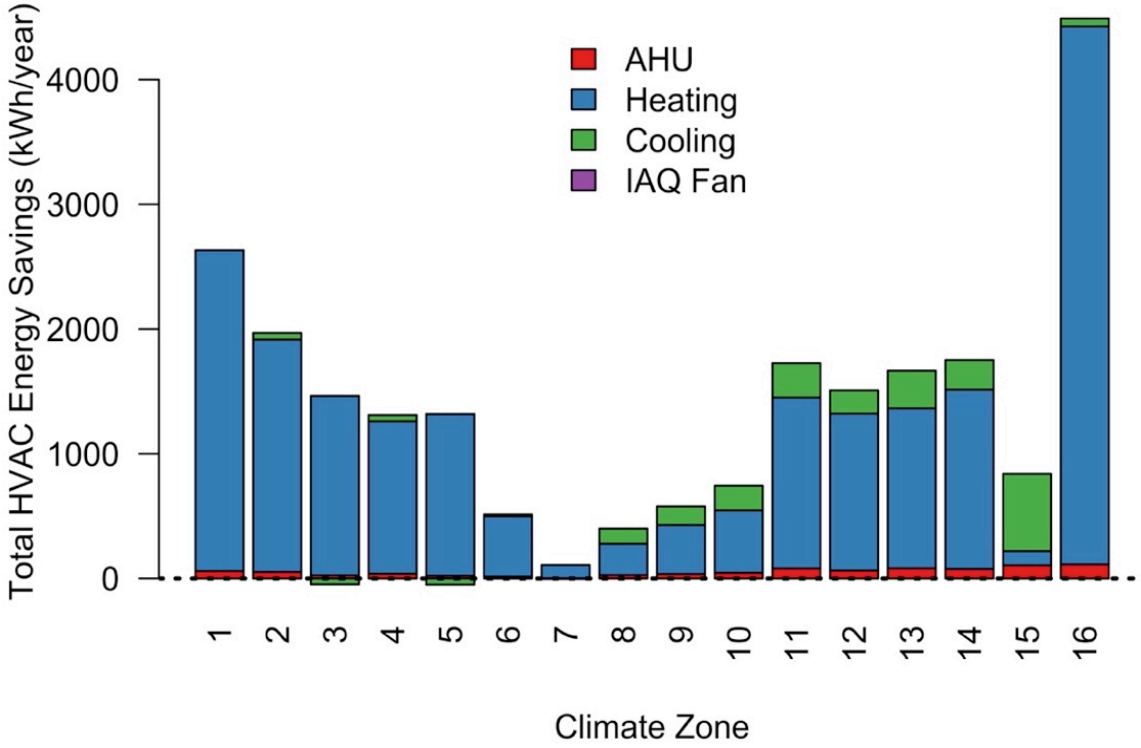
Moisture Mitigation Measures

- HVAC supply air provided to the attic volume at a rate of 50 cfm/1000 ft^2 of attic floor area.
- Air impermeable insulation at the roof deck per California Residential Code (2016) requirements, plus batt insulation to make up remaining thermal resistance.
- 1-perm vapor retarder.
- Mechanical supply fan into the attic volume at 20 cfm or 50 cfm per 1,000 ft^2 of ceiling area.

Simulated Energy Savings (Site)

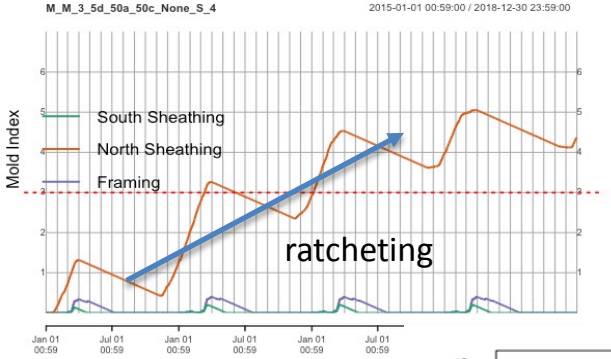
- 18% energy savings
- 8% TDV savings
- Heating dominated

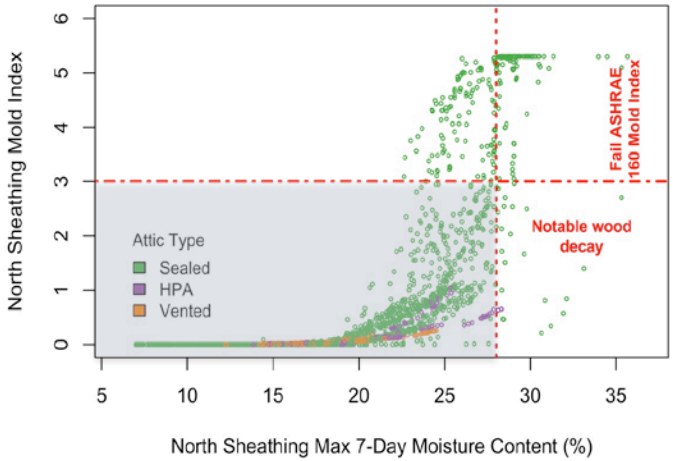
For existing homes with leakier, less insulated ducts, savings increase to about 25%.



Simulated Moisture

- Mold index failures occurred in roughly 15% of sealed attics at the North roof deck.
- Failure rates were lower for wood moisture content rot and decay thresholds.
- Failures worse in 1-story homes, for higher occupancy, no IAQ fan operating, & very airtight (1 ACH50) envelopes.
- Climate zone variability: worst locations Pacific coastal and Central Valley locations.





Answers to Key Questions

There were two key questions to be answered by this study:

- Q1. Do fibrous insulation approaches result in a sealed and insulated attic that can be considered thermally within conditioned space with consummate energy savings?
- A1. Yes – temperature differences are small between the house and attic, and this insulation approach leads to statewide total HVAC energy savings of 18% in terms of site energy and 8% for TDV energy.

- Q2. Does moisture and air permeable insulation used in new California homes lead to increased moisture risk or definite moisture problems in the state's climate regions?
- A2. Yes – there are increased risks of moisture issues using vapor and air permeable insulation, particularly for north facing sheathing in homes with high occupant density that are poorly ventilated. There is considerable climate variability with no uniform trend from warm to cool climates.

Conclusions/Recommendations

- Thermal
  - Insulate to same level as flat ceiling
  - Attic should be as tight as the rest of the house
  - Insulate the gable ends to same R-value as pitched roof surfaces
- Moisture
  - Current model code requirements (IECC Section R806.5) for sealed attics may be inadequate:
    - High surface RH is an issue, NOT just condensation
    - HVAC Supply register in the attic worsened moisture performance in CA homes*
  - New vapor control options should include**:
    - A vapor retarder on the insulation surface (no energy penalty)
    - Supply ventilation to the attic
  - Current Title 24 home ventilation and duct leakage requirements all help to reduce moisture issues
  - Need to revisit validity of ASHRAE 160 moisture design methods in actual assemblies

* This approach was developed based on homes in humid climates and does reduce spring time humidity

** Another possibility is to add a vapor diffusion vent – not evaluated in this study but ongoing work in this area

Other resources:

US DOE Building America study in NE – similar findings

For more details on this study:

Less, B., Walker, I. and Levinson, R. 2016. A Literature Review of Sealed and Insulated Attics – Thermal, Moisture and Energy Performance. Lawrence Berkeley National Laboratory LBNL1006493. https://doi.org/10.2172/1340304

Less, B., Walker, I., Slack, J. and Levinson, R. 2018. Measured Thermal and Moisture Performance of Air Sealed and Insulated Attics with Porous Insulation. Proc. ACEEE Summer Study 2018. ACEEE Washington, DC.

Walker, I.S. and Less, B. 2019. Measured Moisture Performance of Sealed and Insulated Attics with Permeable Insulation in California Homes: abstract accepted by Thermal Performance of the Exterior Envelopes of Buildings XIV (in prep).

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The project report can be found at https://www.energy.ca.gov/2019publications/CEC-500-2019-039/CEC-500-2019-039.pdf.