Evaluating Sealed Attics for ZNE Homes

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CEC, EPIC, EPC-14-012

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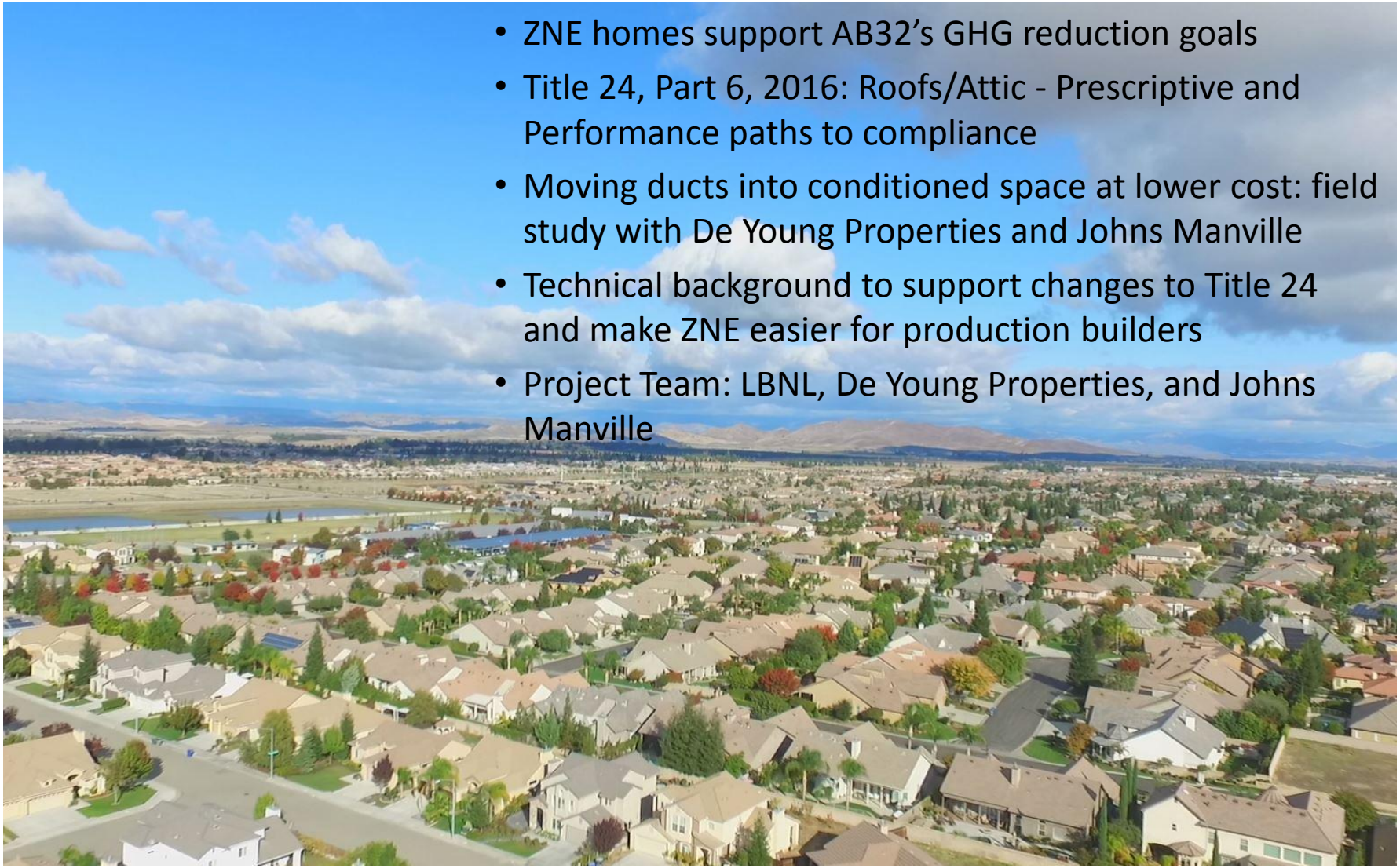
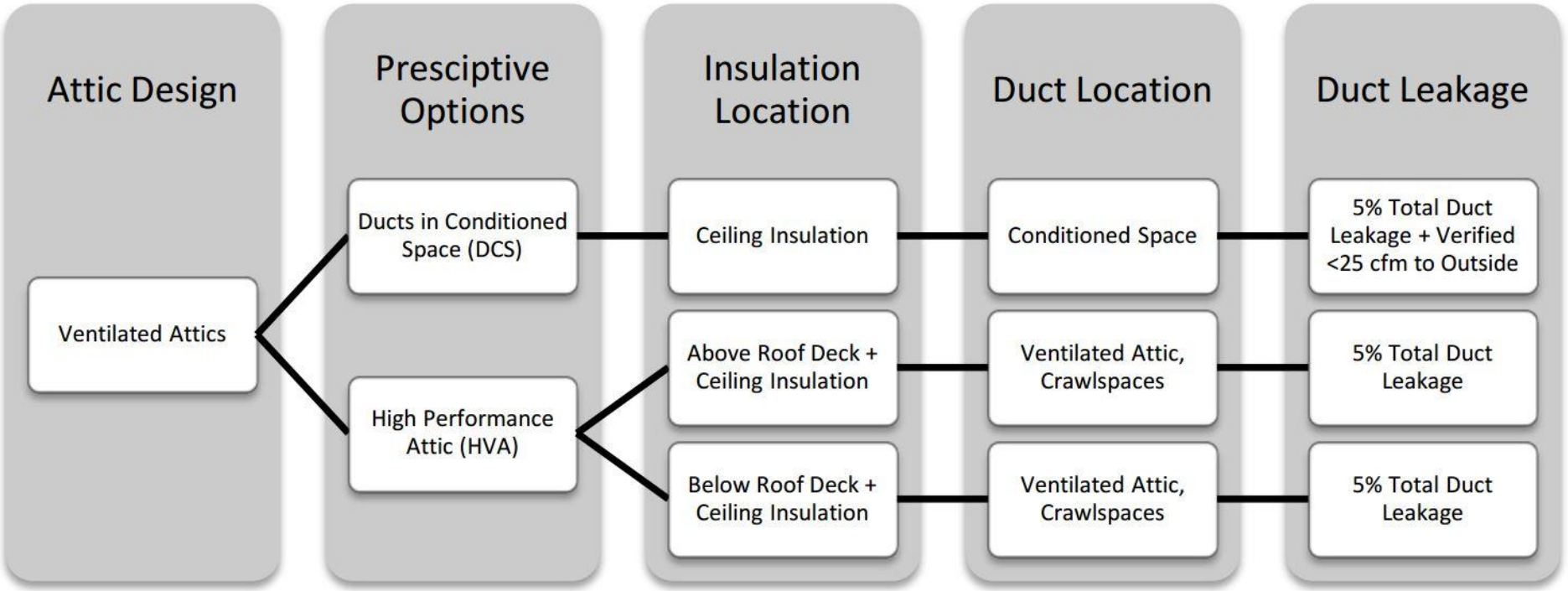
Project Overview



- ZNE homes support AB32's GHG reduction goals
- Title 24, Part 6, 2016: Roofs/Attic - Prescriptive and Performance paths to compliance
- Moving ducts into conditioned space at lower cost: field study with De Young Properties and Johns Manville
- Technical background to support changes to Title 24 and make ZNE easier for production builders
- Project Team: LBNL, De Young Properties, and Johns Manville

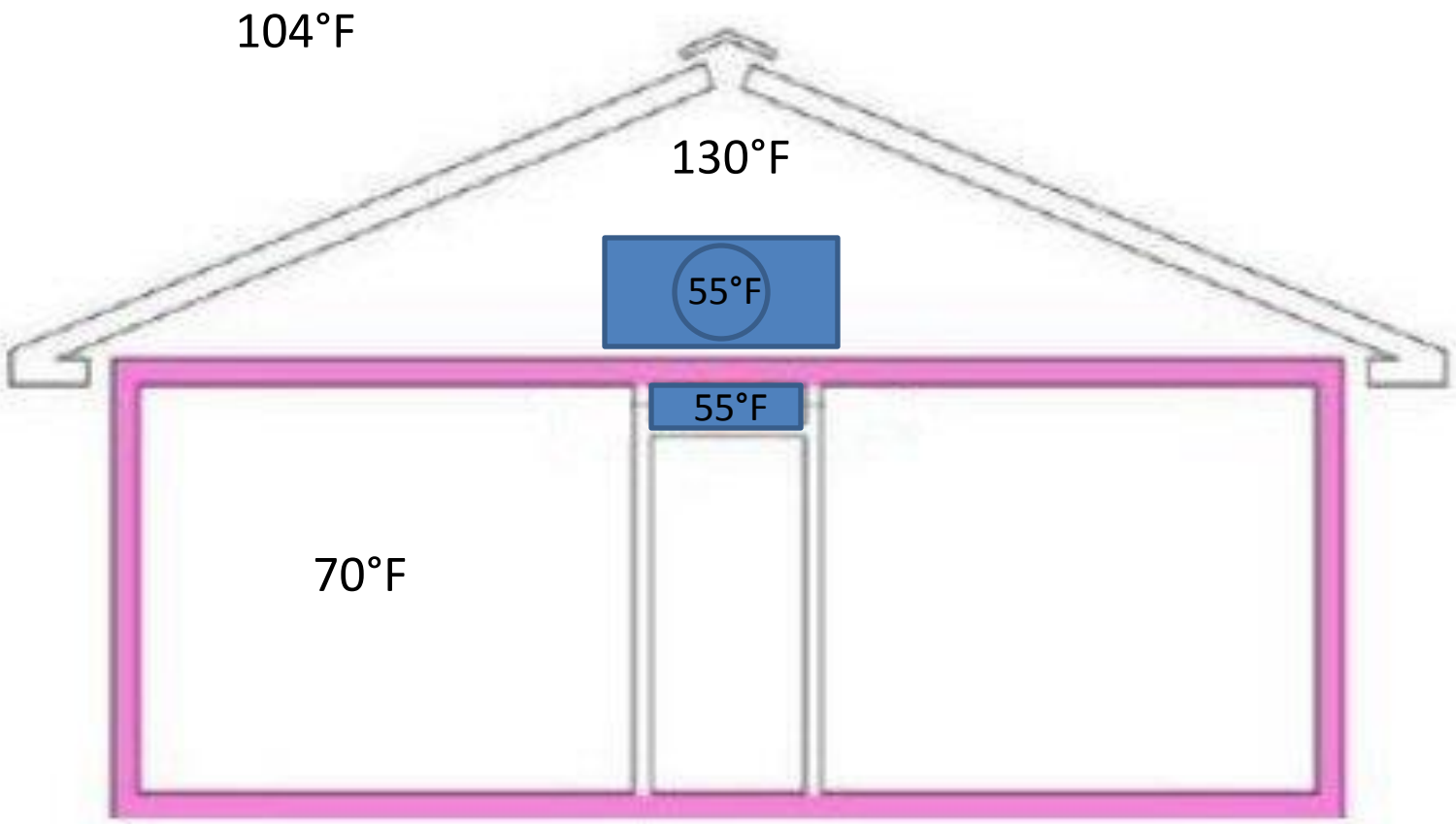
T24 (part 6) Roof/Attic, Prescriptive Approach

Figure 4-8: Ventilated Attic Prescriptive Compliance Choices



Source: California Energy Commission

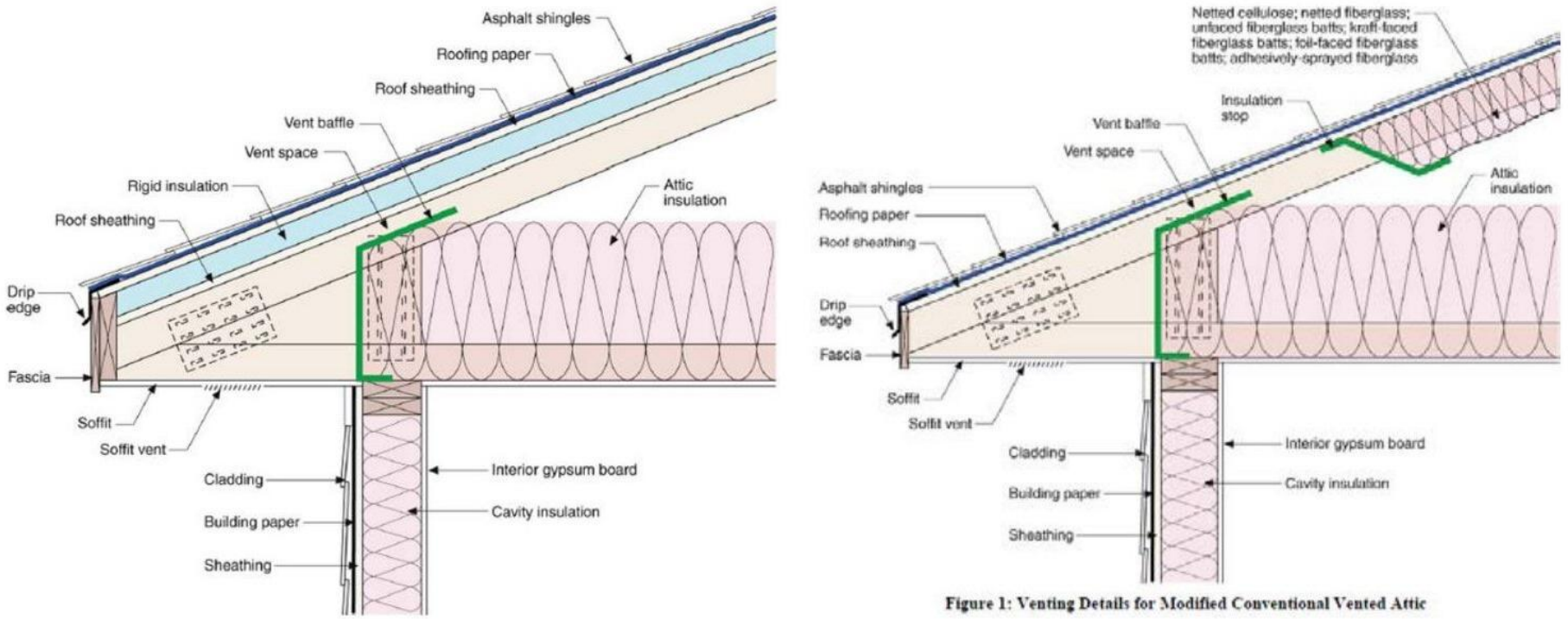
T24 (part 6) Roof/Attic, Prescriptive Approach



source: ductsinside.org

Roof/Attic, Prescriptive: Options A and B

Figure 3-18 - Option A (left) and Option B (right)



Source: Building Science Corporation

Roof/Attic, Prescriptive: Options A and B

Figure 3-16: Prescriptive Requirements for Roof/Ceiling Insulation (§150.1(c)1)

Strategy		How to Comply
High-Performance Ventilated Attics		
Option A	Vented attic with continuous insulation applied above the roof deck. (Figure 3-18). Ceiling insulation required separately above finished attic ceiling.	Table 150.1-A of the Energy Standards Roof Assembly Option A
Option B	Vented attic with batt, spray in cellulose/fiberglass secured with netting, or SPF. (Figure 3-18). Ceiling insulation required separately above finished attic ceiling.	Table 150.1-A of the Energy Standards Roof Assembly Option B
Ducts in Conditioned Space		
Option C	Vented attic with no insulation at roof deck. Ceiling insulation required separately above finished attic ceiling. Ducts and air handler equipment in conditioned space that is NOT a sealed attic.	Table 150.1-A of the Energy Standards Roof Assembly Option C Form: CF2R-MCH-20b

Roof/Attic, Prescriptive: Options A and B

Figure 3-17: Checklists for Prescriptive Requirements for HPVA/DCS for the related climate zones

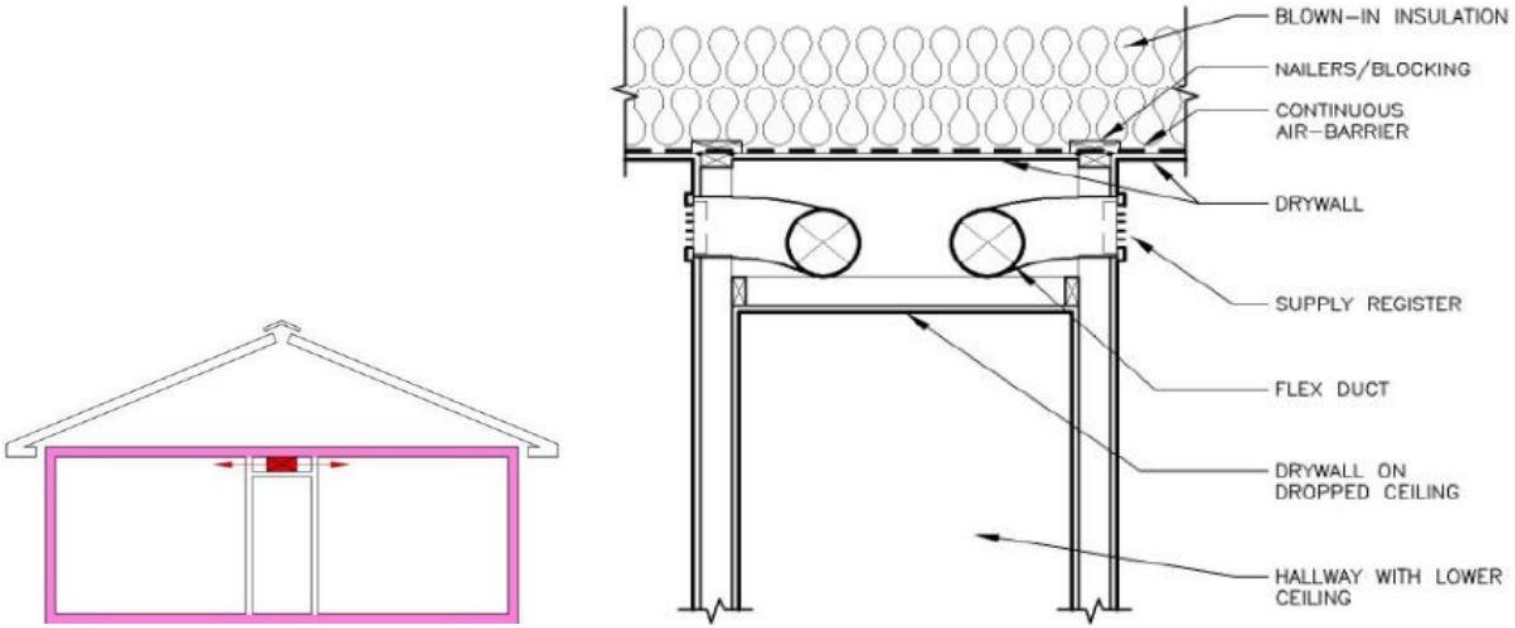
Option A (CZ 4, 8-16)	Option B[1] (CZ 4, 8-16)	Option C (CZ 4, 8-16)
☐ Vented attic ☐ R6 (air space) or R8 (no air space) continuous above deck rigid foam board insulation ☐ R38 ceiling insulation ☐ Radiant Barrier ☐ R8 duct insulation ☐ 5% total duct leakage	☐ Vented attic ☐ R13 (air space) or R15 (no air space) batt, spray in cellulose/fiberglass below roof deck secured with netting, or SPF ☐ R38 ceiling insulation ☐ R8 duct insulation ☐ 5% total duct leakage	☐ Vented attic ☐ R30 or R38 ceiling insulation (climate zone specific) ☐ R6 or R8 ducts (climate zone specific) ☐ Radiant Barrier ☐ Verified ducts in conditioned space
[1] Standard Design used to set the energy budget for the Performance Approach.		

Roof/Attic, Prescriptive: Option C, Ducts in CS

A. Vented Attic, Dropped Ceiling

This strategy places ducts within the thermal envelope without affecting the standard construction of the attic space. This strategy works well in linear plans where rooms branch out from a central hallway with the dropped ceiling.

Figure 4-10 Ducts in Conditioned Space using a Dropped Ceiling



Source: www.ductsinside.org/

Roof/Attic Prescriptive: Option C, Ducts in CS

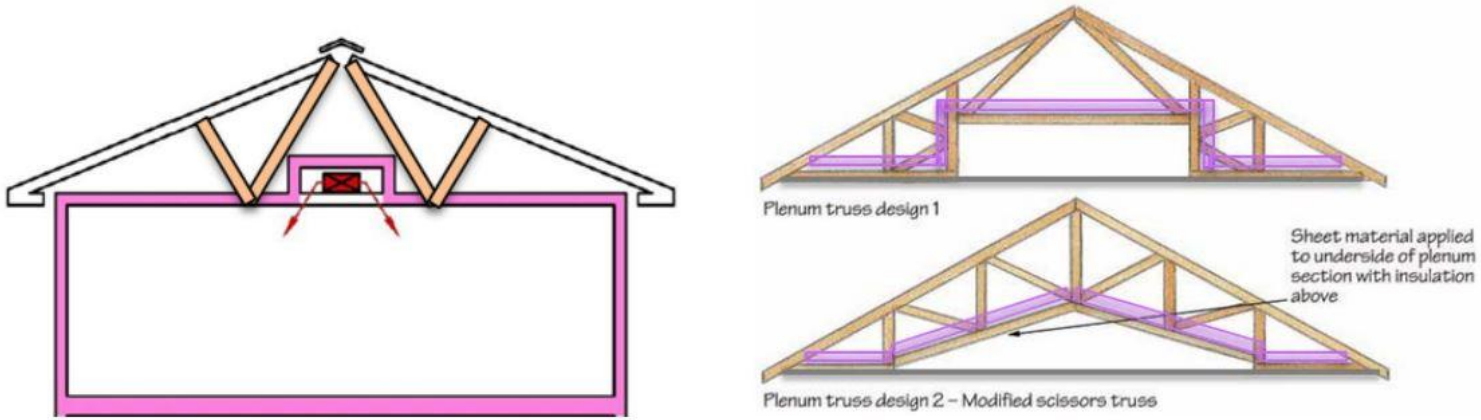
Figure 4-11 Ducts Routed through a Dropped Ceiling

Source: BIRA Energy

Roof/Attic, Prescriptive: Option C, Ducts in CS

Building HVAC Requirements – Air Distribution System Ducts, Plenums, and Fans Page 4-41

Figure 4-12: Plenum Truss Design Example



Source: www.ductsinside.org

Similar to a dropped ceiling, this design is easier with a linear plan that allows for the conditioned space in the attic to cover a central "spine" throughout the floor plan that can reach all spaces in need of supply registers. This design option allows for ducts in the attic space and does not affect aesthetics of the home.

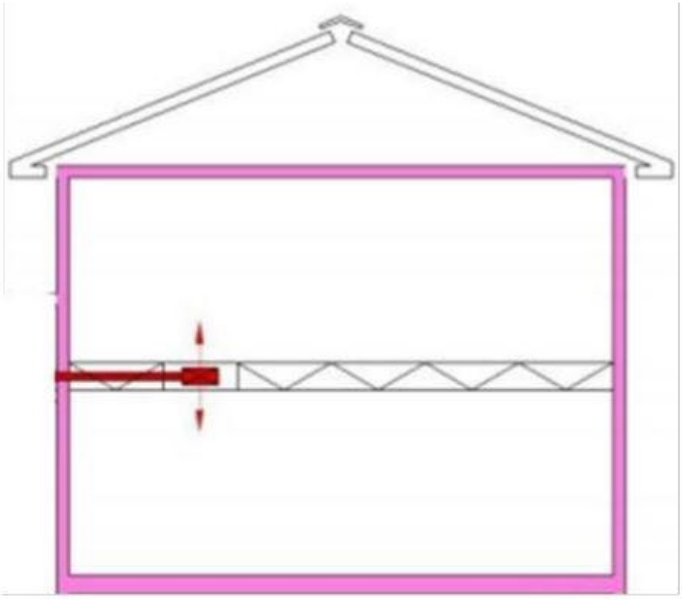
Benefits for selecting the strategy:

1. Vented attic space, same as standard construction
2. Aesthetically less disruptive than dropped ceiling
3. Works with simple and linear designs with rooms off main hallway

Roof/Attic, Prescriptive: Option C, Ducts in CS

C. Vented Attic, Open Web Floor Truss

Figure 4-13: Open Web Floor Truss Example

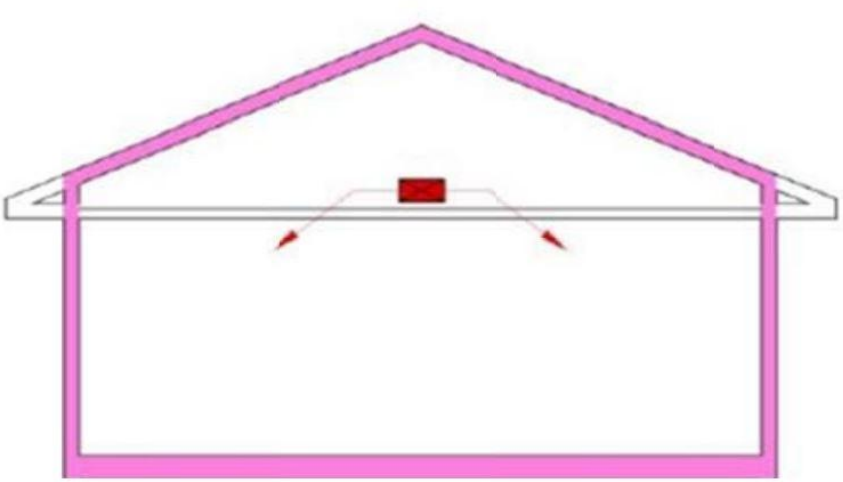


Source: www.ductsinside.org

This option can work for two-story construction and makes use of the space between floors to house ducts. Open-web floor trusses are not a common component in residential construction but are available from several floor joist manufacturers. The depth of floor joists may need to be increased to create a large enough space for supply ducts.

T24 (part 6) Roof/Attic, Performance Approach

9.1.4 DCS – Unvented attic (Sealed)



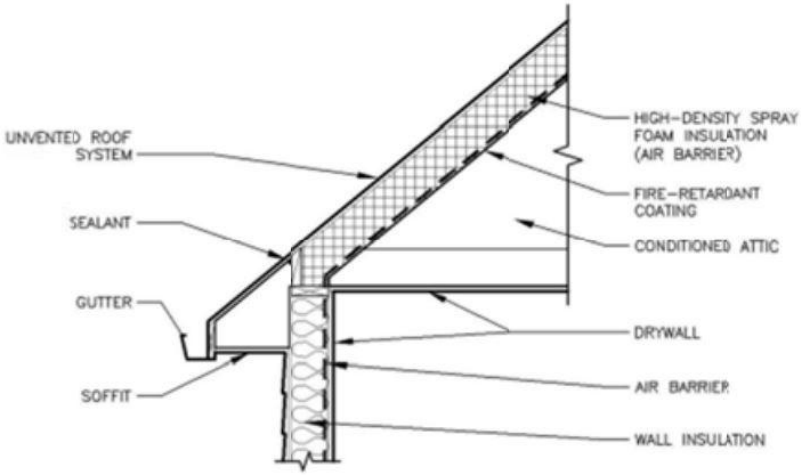


Figure 5: Unvented Attic (adopted from Ductsinside.org)

Interviews with industry experts on high performance buildings shows that insulating the roof deck and sealing the attic space is a commonly constructed option for getting ducts in conditioned space. This design allows for ducts and equipment to be placed in the attic, which is in line with current construction practices. The main change is that the insulation is moved from the ceiling to the roof line – effectively extending the building thermal enclosure to the physical enclosure of the house.

Roof/Attic, Performance Approach

The provisions of CBC, Title 24, Part 2, Vol. 2.5, Section R806.4 describes conditions for insulation placed at the roof of the building as opposed to on top of the horizontal ceiling. Unvented attic assemblies are allowed provided that:

1. **Air-impermeable** insulation is used below and in direct contact with the underside of the roof sheathing.
2. **Air-permeable** insulation is used below and in direct contact with the underside of the roof sheathing and rigid board or sheet insulation of at least R-4 is used above the roof sheathing.
3. **Air-impermeable** insulation is used below and in direct contact with the underside of the roof sheathing, and an additional layer of air-permeable insulation is installed directly under the air-impermeable insulation.

Check with the local building jurisdiction to determine its specific requirements for unvented attic conditions.

Combining this strategy with the additional design improvement of low air leakage for the rest of the building would achieve energy savings and compliance energy credit. Furthermore, this design eliminates the need to seal or limit penetrations at the ceiling level, such as recessed cans, because the air and thermal boundary is now located at the roof deck.

Sealed Attic Advantages/Benefits

- Moves primary air and thermal barriers to the roof deck, which permits complex ceiling designs, ceiling height changes and numerous ceiling penetrations from lighting and services.
- Some unvented attic designs can easily accommodate complex roof plans, which are very difficult to vent properly.
- Eliminates wind-driven snow in cold climates, wind-driven rain penetration in coastal climates, and wind-driven embers from wild fires.
- Relative to traditional vented attics, unvented attic air temperatures are generally warmer during winter and cooler during summer.
- Due to the tight coupling of house and attic air temperatures, HVAC loads are often reduced, for systems located in the attic.
- Remaining thermal losses from the HVAC system, due to air leakage for example, are recaptured in the home's conditioned space.
- As a result of improved thermal performance, air conditioner capacity may be reduced by approximately 0.5 refrigeration tons for a typical sized home.
- Reduces peak demand during afternoon summer cooling periods.
- Reduces potential for condensation to occur on HVAC ducts in cooling operation.
- Placing ducts in conditioned space can help to eliminate air pressure differences throughout the home that are induced by HVAC operation.

Sealed Attic Disadvantages/Risks

- Concerns of moisture loading of attic framing and roof deck.
- Increases roof surface area for air leakage and heat loss/gain (combined sloped roof and gable surface area exceeds attic floor area), and increases material costs for insulation.
- Increases temperature difference across the thermal boundary during cooling hours (shingles-to-attic-air vs. attic-air-to-house).
- Increases roof shingle and structural sheathing temperatures.
- It may be substantially more difficult to install insulation at the structural roof sheathing than on the flat ceiling.
- Any gas appliances located in an unvented attic must use sealed combustion, because they lack combustion and ventilation air paths to outside.
- Placing insulation at the roof deck can cool the roof sheathing in winter, which might lead to condensation and moisture accumulation in the roof assembly.
- In summer, roof sheathing and cladding temperatures are expected to increase.
- Unvented attics may cost more to build than vented attics.

Field Study with De Young Properties

- De Young Properties, 7000 homes, 3 generations
- Johns Manville, JR Babineau, simulation studies
- Lawrence Berkeley National Laboratory, Residential Building Systems, Heat Island Group
- Energy savings potential: HERS score from 50 > 40
- New construction: 8.2 GWh/year, 1.35 MMtherms/yr, $40 M cumulatively by 2025, 15 yr payback
- Retrofits: 373K homes/yr, AB758, 1500 GWh/yr, 320 Mmtherms/yr, 5% drop in total residential peak

Sealed Attic Innovation

Batt insulation vs. spray foam:

- Spray foam roof deck sealing effective, but expensive - a barrier to adoption. Spray foam concerns include sensitivity to “good” installation and off-gassing of chemicals.
- Can batt insulation produce similar energy savings at significantly lower cost? Batt insulation familiar and therefore favored by contractors and installers.
- Measure moisture dynamics in attic; is there a threat to roof deck or attic framing?
- Refine simulation modeling; enable performance predictions in other climate zones.
- More reassuring health profile with batt insulation.

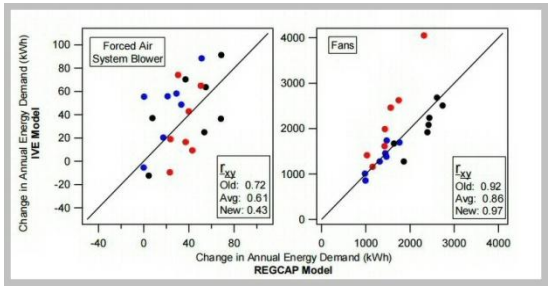
Benefits of moving HVAC into conditioned space:

- Significant energy savings; 13-18% in new construction, 25 – 50% in retrofits.
- Residential peak load reduction supports grid reliability.
- Occupant comfort with rapid cool down.

Technical Tasks

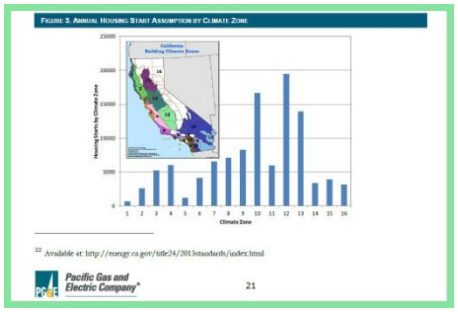
Field monitoring the homes of the future

- First Fresno home to exceed Title 24 by 30%
- Second Fresno home to outperform the first
- 122 monitored points in each house
  - temp, RH, SC, WMC, heat flux, HVAC power, solar irradiance, wind, weather



Simulation of Attic and HVAC system performance

- Determine optimal specifications for all 16 CA climate zones
  - Roof deck insulation, air tightness, roofing materials, thermal mass
- Refine REGCAP simulations using field data

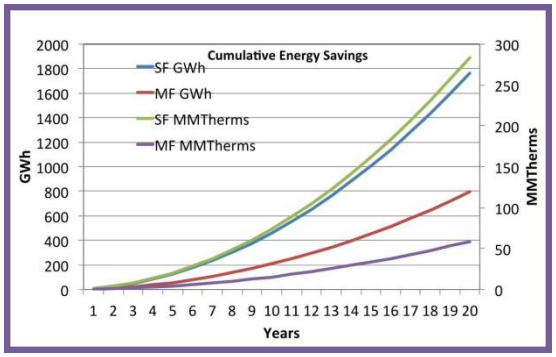


Literature review

- Compilation of existing literature exploring alternative attic construction
- Summarize performance, construction specs, cost estimates, etc.
- Analyze as guide to simulation and field study tasks

Evaluation of project benefits

- New construction: Drop HERS score from 50 to 40, help reach ZNE
  - 8.2 GWh/yr, 1.35 MMtherms/yr, $40 M cumulatively by 2025, 15 yr payback
- Retrofit potential: 30%$^{+}$ savings, 373K homes/yr, jobs program
  - 1,500 GWh/yr, 320 MMtherms/yr, $530 M/yr, 5% drop in residential peak



Field Monitoring

- Fresno home to exceed Title 24 by 30%
- Second Fresno home to outperform first
- 122 monitored points in each house
  - temp, RH
  - surface condensation, WMC
  - heat flux, HVAC power
  - solar irradiance, wind, weather

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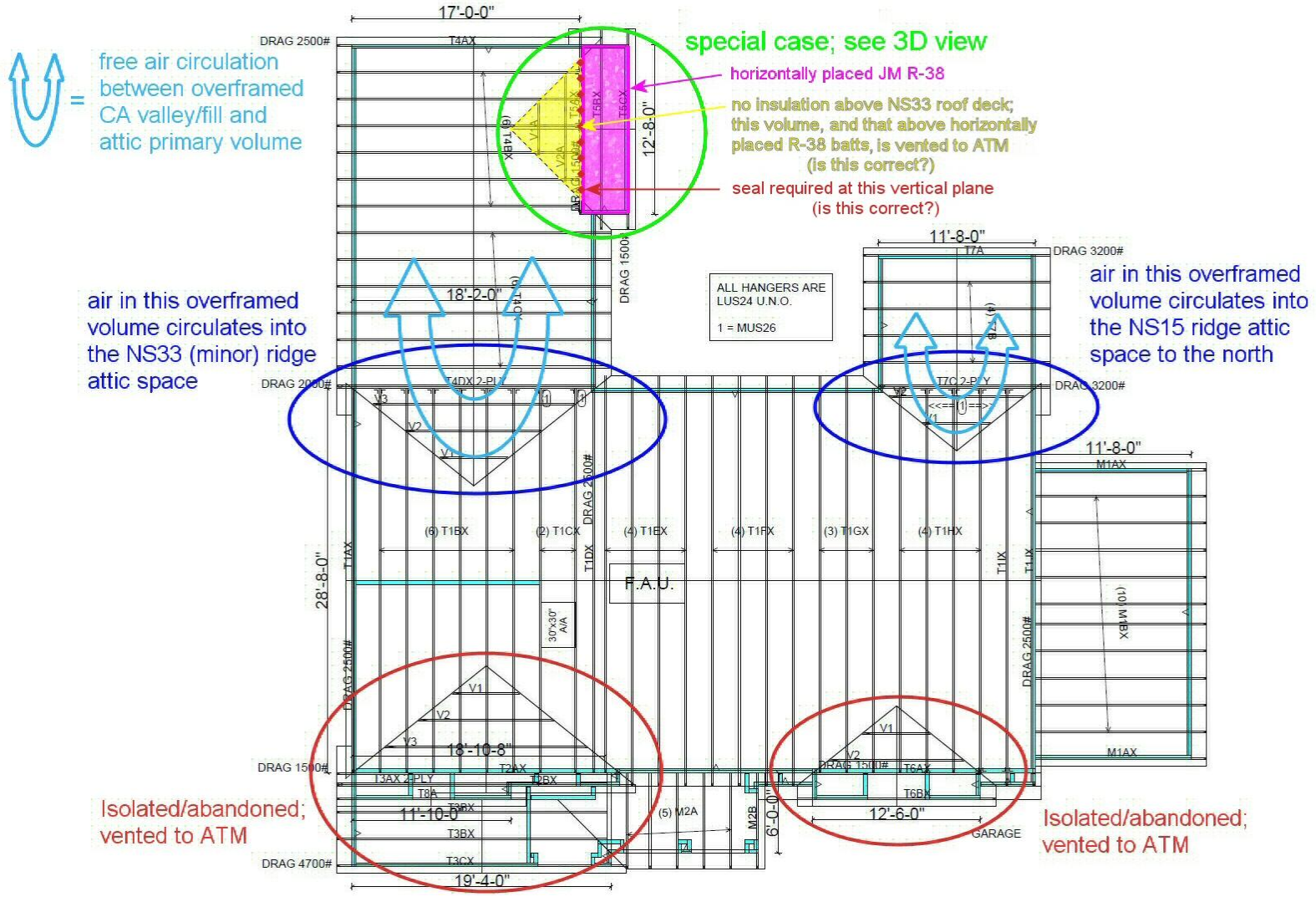
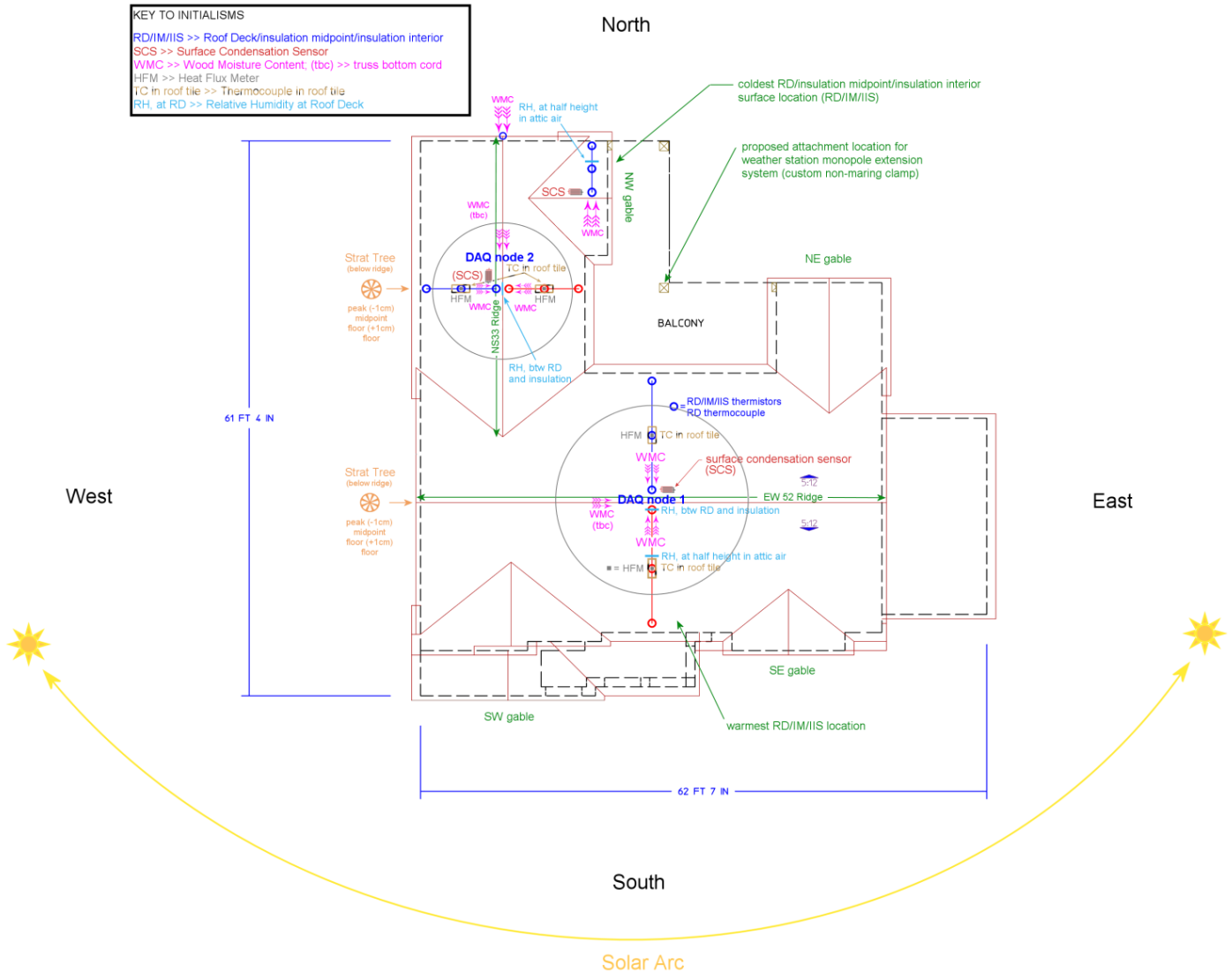
Field Testing: Sensors and Data Acquisition

Evaluate roof/attic design, solar path, vulnerable locations, air circulation…



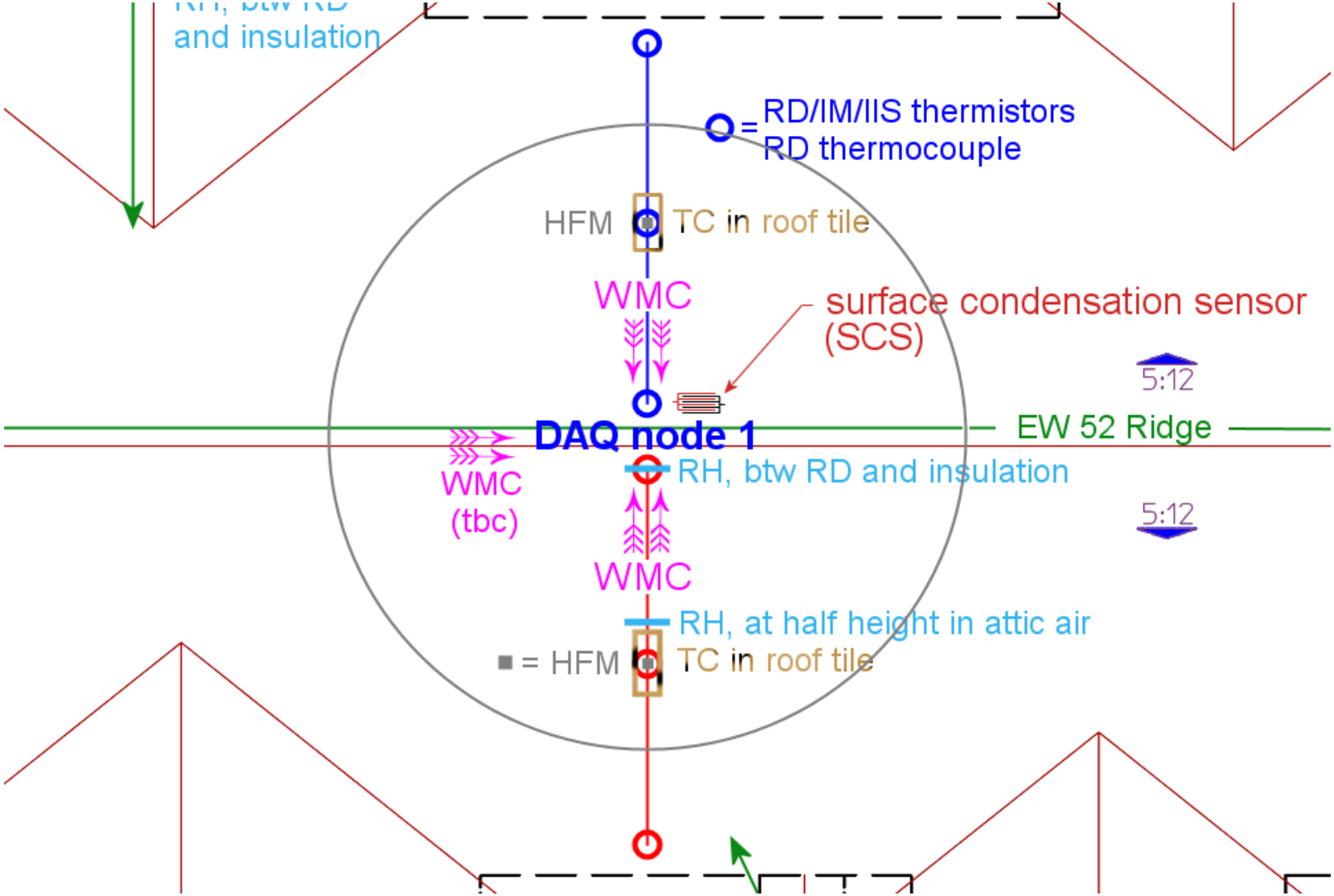
Field Testing: Sensors and Data Acquisition

Map out strategic sensor distribution and positioning…



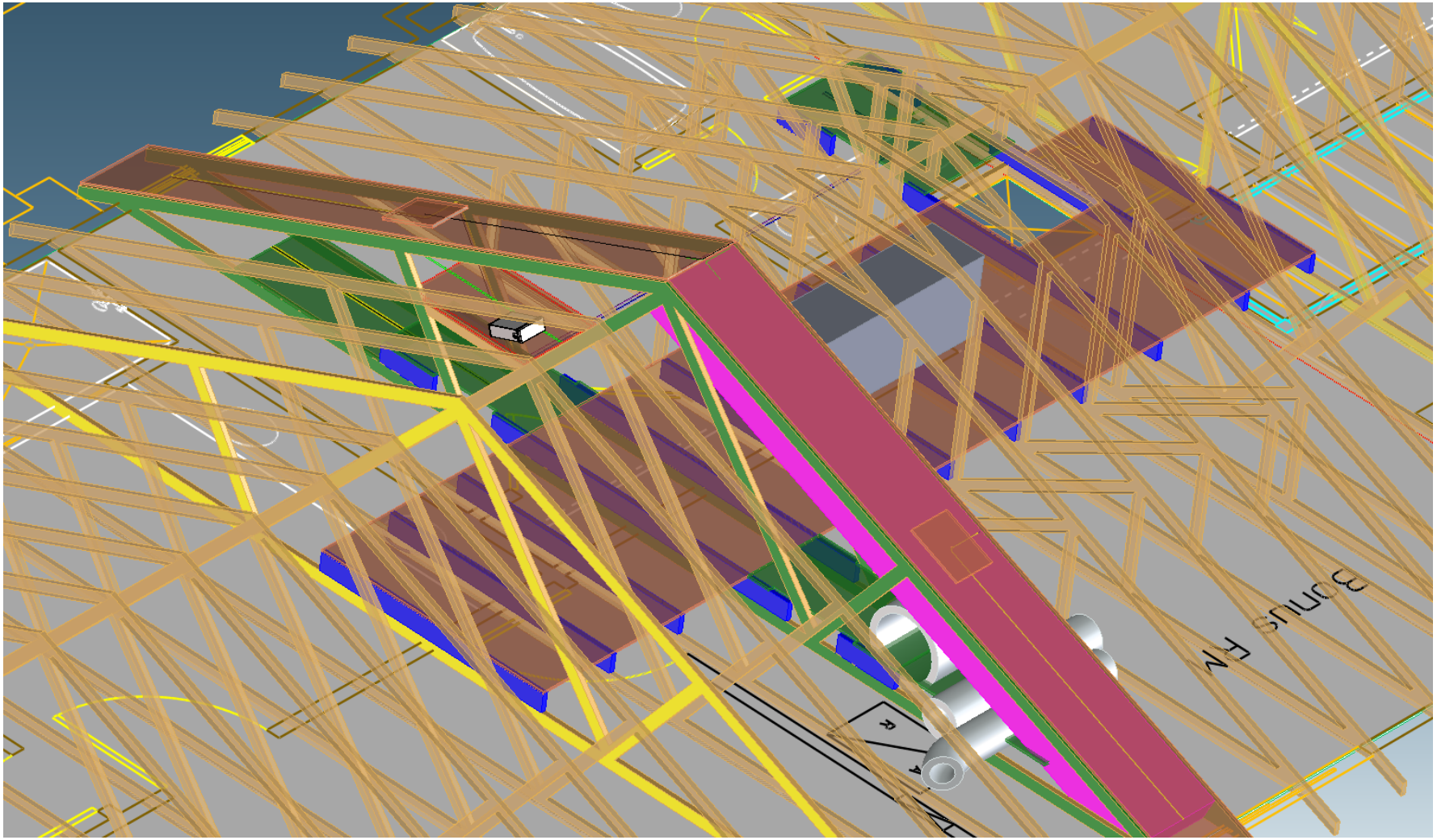
Field Testing: Sensors and Data Acquisition

Select and/or design sensors and plan out integration methods…



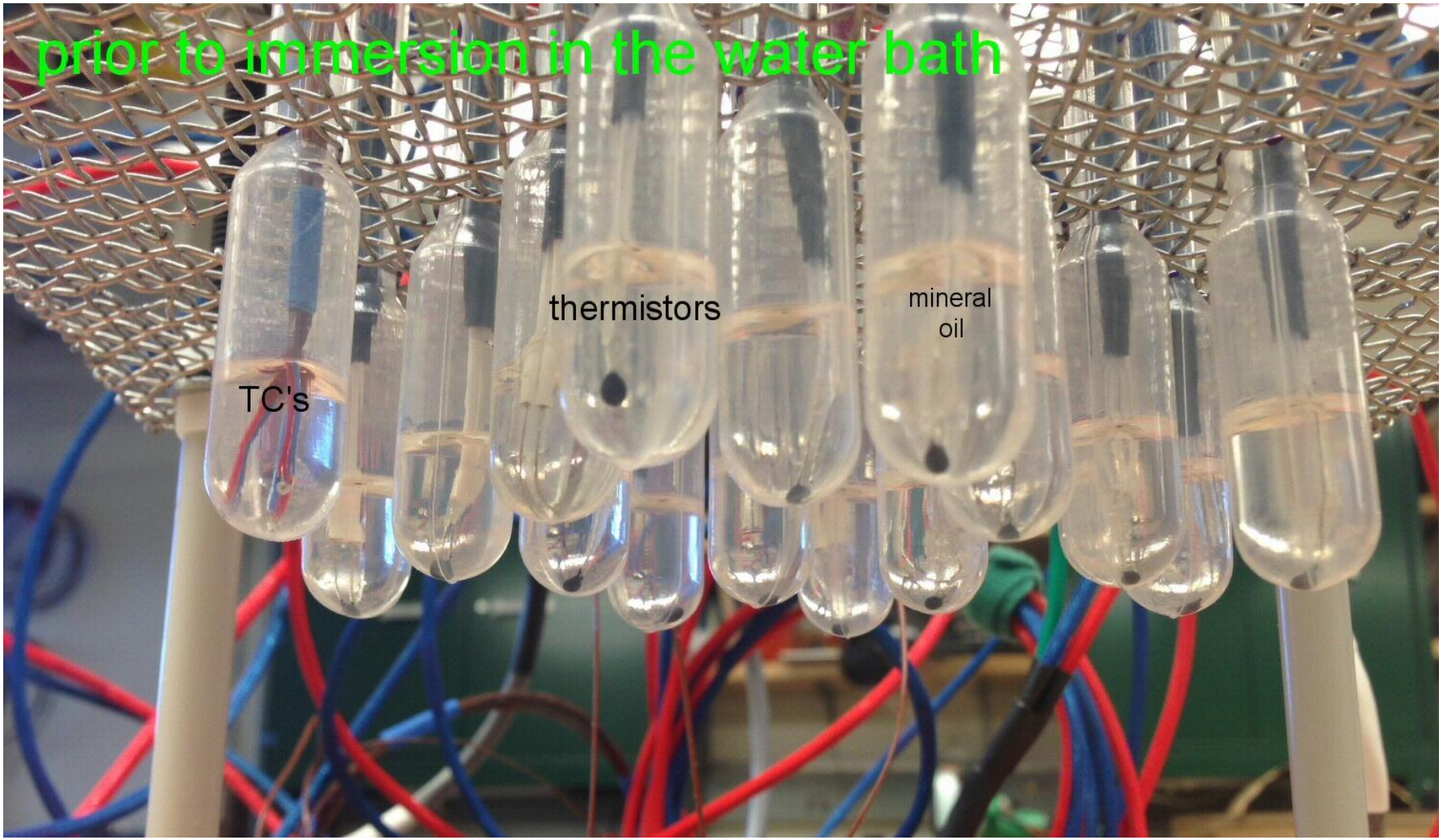
Field Testing: Sensors and Data Acquisition

Model space, identify possible conflicts, duct runs, wiring options…



Field Testing: Sensors and Data Acquisition

Calibrate thermistors and thermocouples individually…

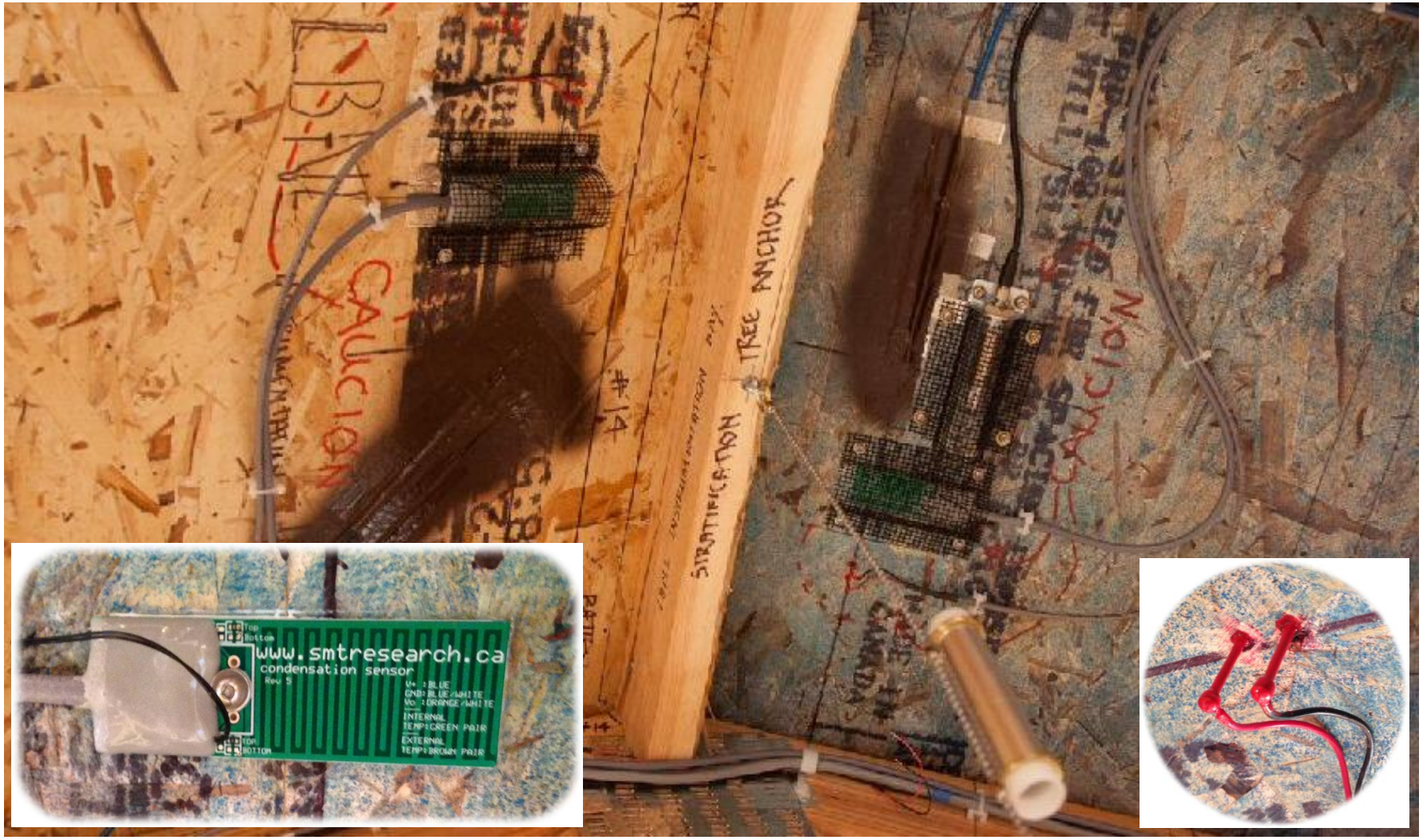


Field Testing: Sensors and Data Acquisition

Sensor installation … Hukseflux HFS

Field Testing: Sensors and Data Acquisition

Sensor installation … SCS, WMC, RH, Thermistors, TC's, Stratification tree



Field Testing: Sensors and Data Acquisition

Sensor installation … roof tiles thermally monitored at surface and underside

IRC Requirements (Table R806.4):

- In inland CA climates – no exterior roof deck insulation required if a tile roof is used
- May need this extra insulation in other locations and for non-tile roofs

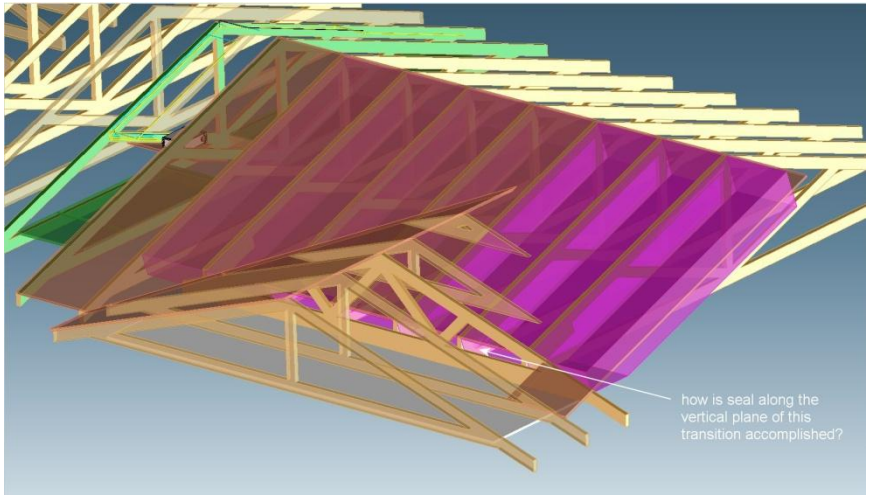
Field Testing: Sensors and Data Acquisition

Sensor installation … weather tower

DAQ nodes supported by Keysight 34972A

- 122 monitored points in each house
- Cradlepoint MBR1400 cellular modem VPN back to LBNL
- Self initializing and configuring upon power restoration
- Tolerant of internet failure; all data stored locally

Predicted and Discovered Challenges



CAD modeling helps predict:

- How to handle complex gable structures
- Geometric sealing challenges
- HVAC and insulation interference
- DAQ node locations and sensor wiring runs
- Sensor placements, esp. relative to roof battens

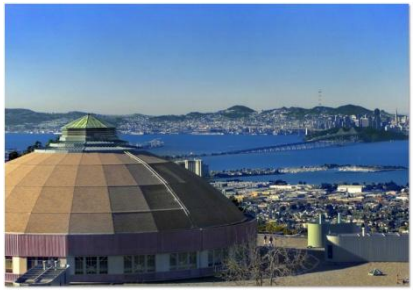
Real-Time Challenges:

- Communicating modified construction to subcontractors and their teams
- Engagement of subcontractors with objectives
- Need to check that work has been completed as intended
- Time with code officials to explain adaptations and seek their buy-in

Project Team

BERKELEY LAB

Iain Walker
Ronnen Levinson
Jonathan Slack
Brennan Less
Anna Liao
Stephen Czarnecki
Woody Delp
Darryl Dickerhoff



Brandon De Young

Broken Drum Insulation
DuctTesters
BIRA Energy

de young properties

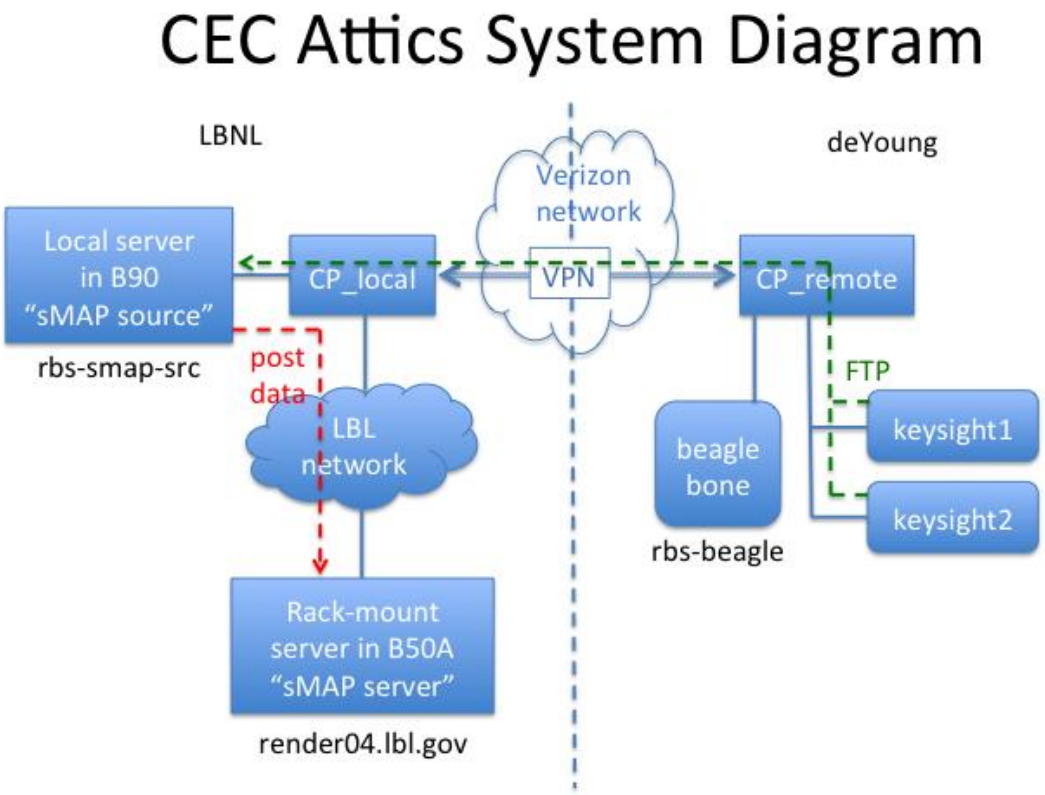
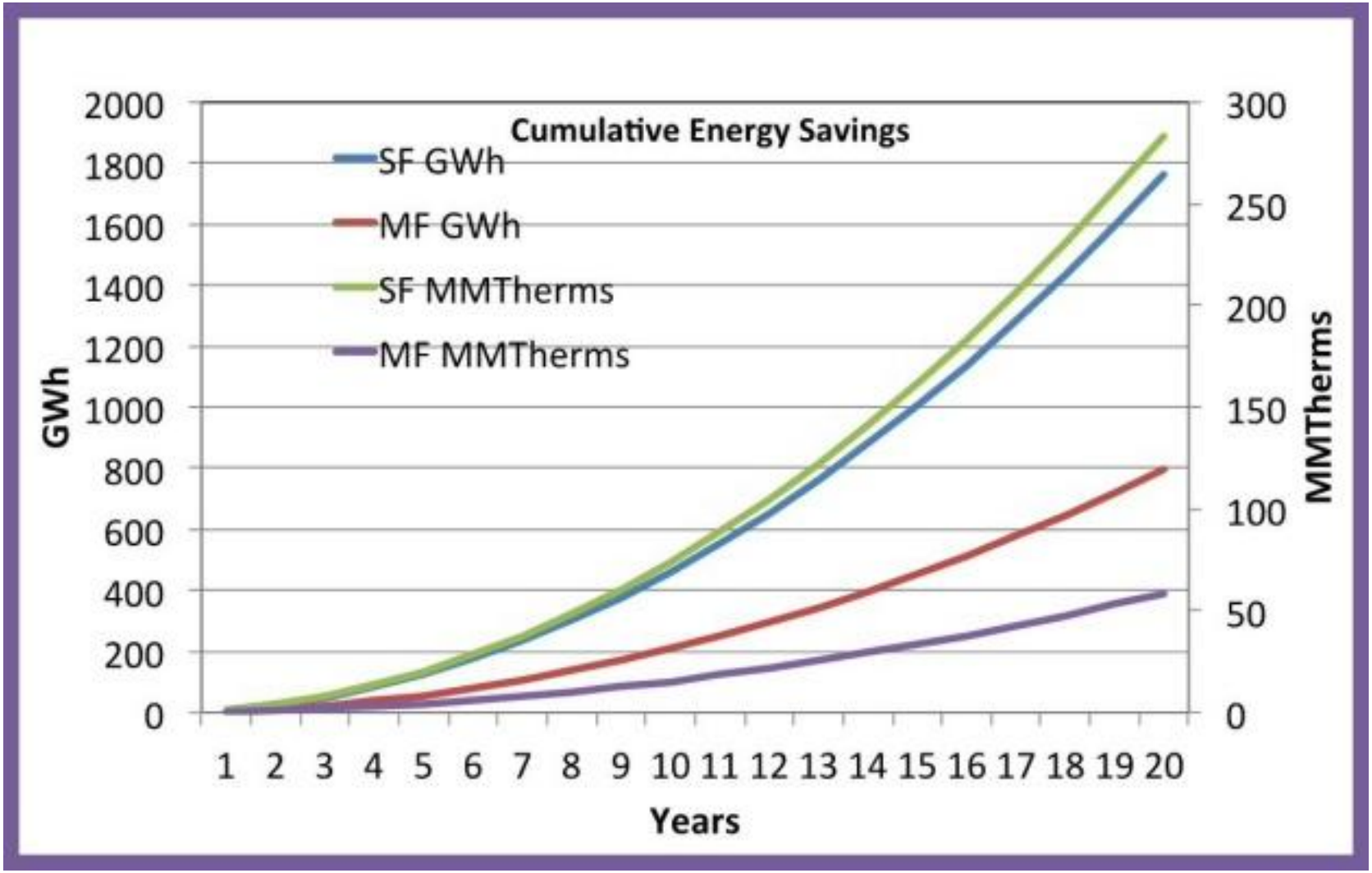
Johns Manville

Francis (JR) Babineau

Elam Leed

Todd Bridgeford

Data Management



Energy Savings