Scalable Thermal and Resilience Exterior Envelope Strategies for the Manufactured Housing Sector

Lessons learned thus far

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Why is it critical to research manufactured home decarbonization and resilience?

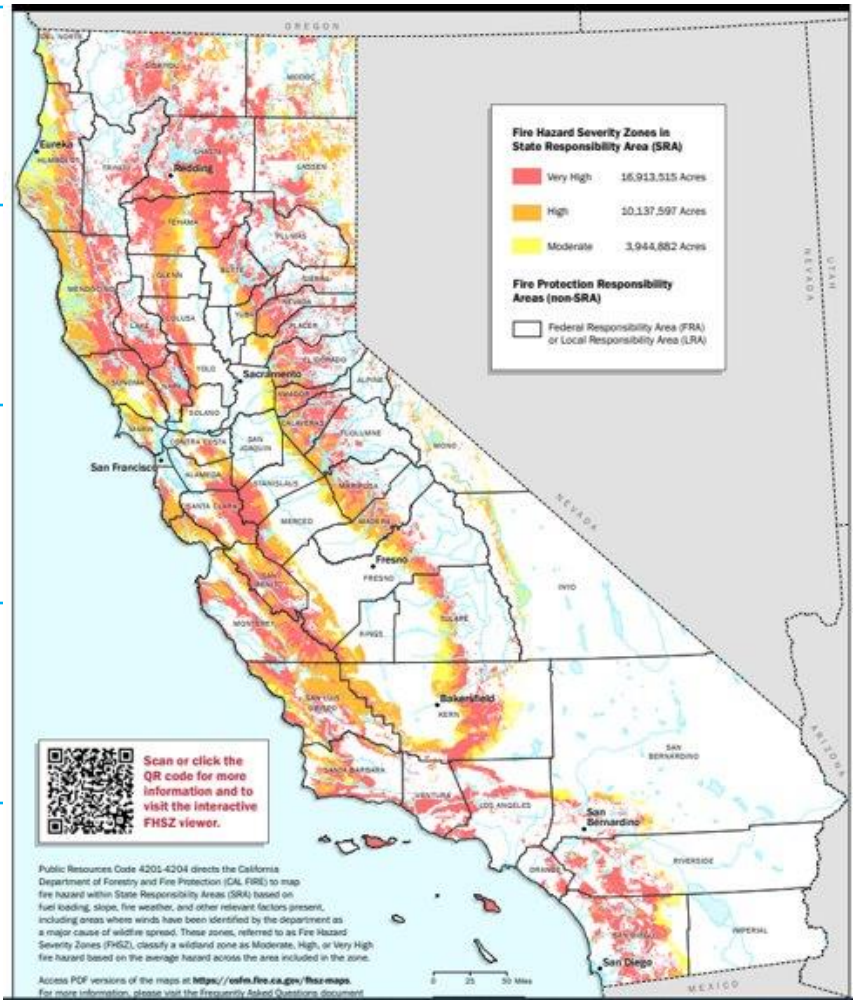
Between 2020-2022, over 80% of new properties built in California were in “high” or “very high” fire hazard zones, due to population pressures.

Fire hazard zones tend to have higher poverty rates.

Manufactured housing is the largest source of unsubsidized affordable housing in the US: 3-4 times cheaper to construct than site-built homes and constitute 10% of new housing starts.

Vulnerable populations, for example retirees and low-income households, are overrepresented in the manufactured housing stock.

Manufactured homes are more likely to be uninsured or underinsured, due in part to insurers’ reluctance to cover manufactured homes



Potential to leverage factory production efficiencies and broaden accessibility

EPC: 19-035 California Title 24 Manufactured Homes

Research Question: What is the least cost and scalable pathway for manufactured homes to achieve all electric, ZNE per Title 24 definitions?

Timeframe: 2020-2026

Objectives: Design, install and test 3 prototype manufactured homes that exceed HUD and meet increased fire and energy standards achieving T24 and DOE ZERH standards

- Low Energy Design Rating
- Low Technology Readiness Level envelope technologies
- Modernized production strategies
- Technology transfer for policy, programs and industry

Single Wide in Yucaipa, CA. EPRI. 2022.

Partners

Prime Recipient: EPRI

Key Partner: SBRA

Funder: California Energy Commission

Site Owner & Operator

Fabricator

Title 24 Verification

M&V

The Regulatory Context

Manufacturing Plant. EPRI. 2022.

- As the State of California marches towards the goals of SB100, the establishment of the Title 24 code for residential new construction puts it on the pathway to achieve deep decarbonization.
- Similarly, California has adopted the Wildland Urban Interface Code (California Building Code Chapter 7A)
- The only exception to the code remains manufactured homes, which are regulated by a pre-emptive Federal (HUD) standard
- The federal HUD standard last had its energy and fire safety standards significantly updated in the 1990s. Primary focus is on reducing fire hazards inside the home.

Advanced Envelope

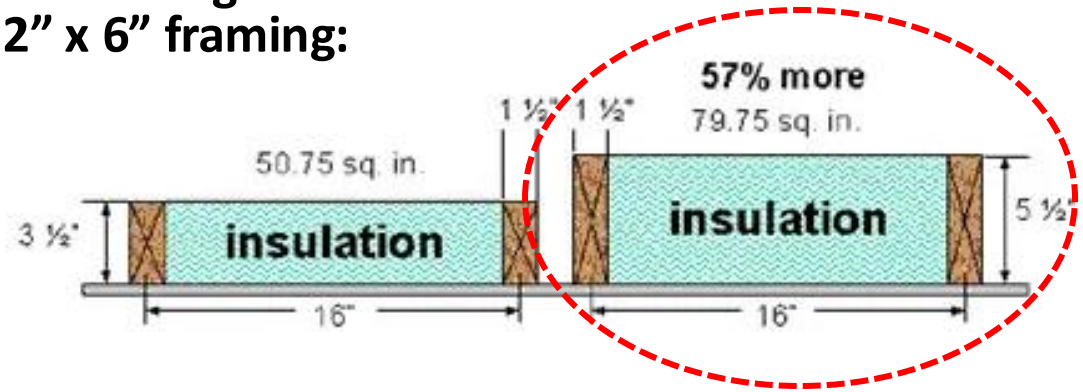
Insulation: Ceiling: R-40; Walls: R-21; Floor: R-21; Belly: R-22; RESNET Grade I installation

Fire resilient specs (WUI): A “first line of defense” approach, incorporating class ‘A’ fiberglass shingles, pop vents with wire mesh screens, fiber cement siding, and tempered glass windows

EPA Indoor AirPlus requirements: Low or no VOC paint, special carpet requirements

Air Sealing: Introduced Advanced and Aerosol Air

2” x 6” framing:



Cool roof shingles:

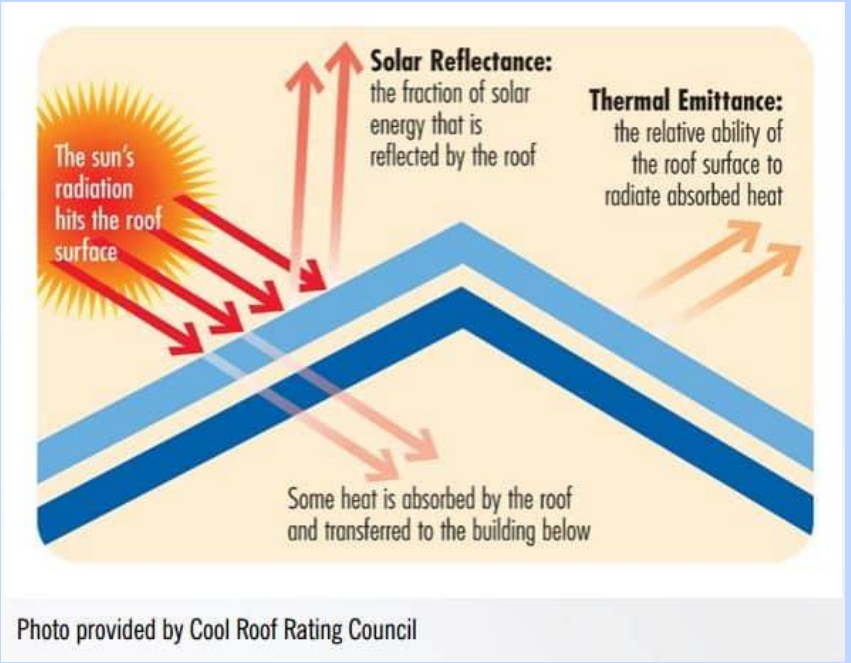
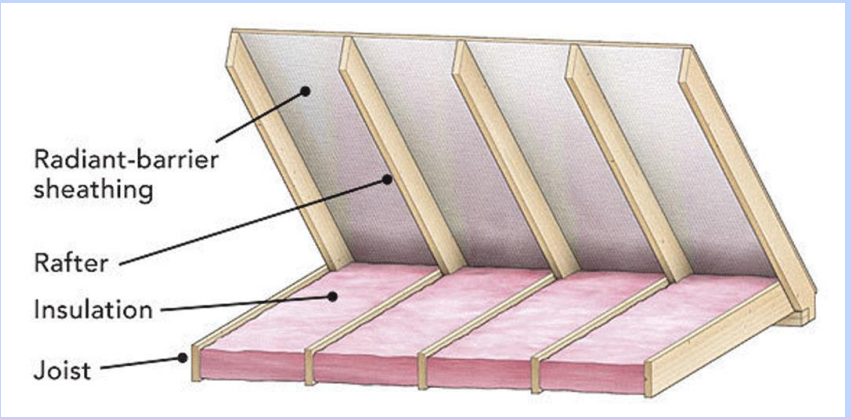


Photo provided by Cool Roof Rating Council

Radiant barrier:



Fine Home Building. 2021.

3 Pilot Homes, 3 Unique Technology Packages

Home A (648 sqft - CZ13)	Home B (648 sqft - CZ10)	Home C (1050 sqft - CZ13)
Prescriptive air sealing	Advanced air sealing	Aerosol spray air sealing
Mini-split HP SEER 19, HSPF 10	Mini-split HP SEER 19, HSPF 10	Package terminal HP 120V
HPWH	HPWH (15-amp)	HPWH
Solar PV: 2.96 KW Solar-ready (site installed)	Solar PV: 3.07 kW Factory installed shingles	Solar PV: 4.44 kW Solar-ready (site installed)
Smart panel for load limiting	Standard panel, low amperage appliances	Smart panel for load limiting

Lessons Learned: Bidding and Permitting

- Lack of consolidation in industry can create cost and performance uncertainty
  - Production
  - Transport
  - Set-Up
  - Retailer/Dealer
- Plants have established products and sourcing channels they use for a code compliant standard
- HUD deliberated extensively on heat pump elements as standards based on alternative technologies

Set up at Visalia manufactured home park. EPRI. 2022.

Reconciling Fire Resilience with Prevailing Practices

- **Issues became apparent with hardening measures targeting a two-hour rating:**
- **Gypsum Wall Boards:** Added weight for transport is prohibitive. Plants unwilling to build, will stop manufacture line for the day to add additional gypsum wall board.
- **Metal skin sandwich panel:** Cost prohibitive, metal skin appearance is extremely unappealing to housing manufacturers (added difficulty to sell), additional fasteners slowing plant production line. Customer appeal (cost, appearance) were important.
- **First line of defense approach** prioritizing noncombustible materials was adopted instead

Rigid foam board installation at plant. EPRI. 2022.

Transport

- Completed homes are often shipped hundreds of miles.
- Foam sheathing is known for increased risk in nail popping due to vibration and wind during transportation

Getty Images. 2024.

Transportation can compromise envelope integrity

Air Leakage Testing

Blower door tests were completed to assess air leakage. Research goal was to stay below 2 ACH50.

	Square Footage	Bldg. Volume (Cu. Ft)	Air leakage @ -50 Pascals (CFM)	ACH -50 Pascals	ACH Natural (no induced air flow)	Air leakage @ +50 Pascals (CFM)	ACH +50
Home A	650	5,200	300	3.46	0.081	410	4.73
Home B	650	5,180	406	4.60	---	486	5.67
Home C	1040	8,320	472	3.40	0.052	780	5.62

Higher than expected ACH50 rates, attributed to marriage line seam and transport damage

Preliminary Findings from Unoccupied Testing

Issues identified during production, transportation, and installation are reflected in energy performance. Measured performance falls short of modeled performance.

While all-electric energy efficient designs do result in lower utility cost compared to typical HUD homes, solar production is primary driver of lowered bills (accounting for **62% of bill reduction**, on average).

Even though performance did not match models, designs still show reasonable payback periods (**18 years**, on average). Average first cost was a little over **$190/sqft**, compared to a baseline of **$125/sqft**.

High demand and significant material shortages at the time of bidding in Q2 2021 drove up production costs

Unoccupied testing took place from September 2023 to September 2024.

Non-Energy Benefits of Fire Resilient Construction–Insurance

Manufactured Homes are more likely to be uninsured or underinsured.

High fire risk zones have seen the highest growth in housing stock in California.

Lowering fire risk can lower insurance premium by up to 55%.

Economic value may be derived from improved insurance cost, which may help improve payback period.

Improved fire resilience may also improve insurance access in this segment.

Important to quantify all value streams

Lessons learned from production builders

- New measures should lend themselves to standardized designs, processes and workforce skills
- Additional workforce training, licensure and coordination especially air sealing measures, among others
- Need for clarifying incremental policy requirements for manufactured homes compared to national standards
- Incentives should make it simple to apply and alleviate costs, concentrating on financial gains and increased home value to attract customers – this is a very cost sensitive segment!

Single and Double Wides in Visalia. EPRI. 2022.

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