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Local Governments Empowering Our Communities

What are Zero Net Energy Homes, and Why Build One?

BayREN Codes & Standards

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What is BayREN?

- BayREN is the Bay Area Residential Energy Network
- BayREN Codes & Standards is a joint effort of Bay Area cities and counties to achieve full compliance with the California Energy Code.
- BayREN trainings provide building department staff and private sector building professionals with tools and strategies for improving energy code compliance.

Today's Topics

1. The definition and history of zero net energy (ZNE) homes
2. Features of ZNE homes
3. The role of renewable energy and energy storage in ZNE homes
4. Examples of ZNE homes
5. Keys to success in designing and building ZNE homes

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Definition & History of ZNE Homes

Basic ZNE Definition

A zero net energy building is one that produces as much energy as it consumes over the course of a year.

Minimize by building a very energy-efficient home

Produce clean energy onsite with a solar array

Annual Energy Consumption

- Annual Energy Generation

Zero (give or take)

ZNE is defined in different ways by different entities in the US.
California's energy code uses "time-dependent valuation" (TDV) of energy.

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Energy Efficiency Throughout History

People have been building for thousand of years with the 'energy efficiency' technologies at their disposal, to achieve comfort and minimize their fuel needs.

Gila Cliff Dwellings | Heart NM

- Earth – clay and stone – is still the most commonly used structural material worldwide
- Sod houses date to the Middle Ages, when wood was scarce
- Straw and other fibers are used in bales, wattles, and many other building methods today

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Energy Efficiency Throughout History

Traditional homes were designed to take advantage of the natural environment to minimize heating and cooling needs

- Orientation for sun, shade, breezes, windbreaks
- Protective overhangs
- Buffer spaces (attics, porches)
- Cross-ventilation for cooling and fresh air
- Sunrooms

Gamble House, 1908, Pasadena, CA

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Energy Efficiency Throughout History

Rising energy costs and concerns about climate change have prompted more focus on tightening the building enclosure and balancing energy use with renewable energy production.

Thrive Homes 2018, Denver CO

- Super-insulated homes in the U.S. began in response to the 70s and 80s energy crisis
- The Passivhaus (Passive House) standard was developed in Germany in the early 1990s
- In 2006, the Metro Denver chapter of Habitat for Humanity provided documentation of the first house in the US fully operating at ZNE
- As of February 2018, >14,000 “ZNE-ish” homes inventoried in the US and Canada

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Present-day Challenges to Energy Efficiency

- Smaller lots
- Random orientation
- Reliance on mechanical heating and cooling that typically under-performs
- Security and privacy concerns often limit window design and placement
- Construction costs are very high
- Increasing electric uses in homes

Multifamily Note

Because tenants benefit the most from energy-efficient apartments, the building owners have less incentive to invest in efficiency. This is a larger issue for retrofits, but also a challenge in new construction.

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Historic Trends Have Driven Up Energy Use

- Relatively low cost of energy
- Increasing income
- Environmental problems were seldom in the forefront

  (*climate change, acid rain, air pollution)*
- Air conditioning has become standard
- Typical house sizes have grown dramatically
- Home appliances boomed (and ballooned)
- Home electronics have exploded

1950

2018

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1970s Oil Crisis Opened Eyes

California's energy efficiency efforts began after OPEC declared an oil embargo in 1973

- The embargo created awareness of the need for energy independence
- Warren-Alquist Act of 1974 spurred creation of the California Energy Commission (CEC) and Title 24 energy code
- CA's energy policy and energy efficiency standards continue to evolve today

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CA Policy Moving Towards ZNE

- 2006: AB32 Global Warming Solutions Act
- 2008: Long Term Energy Efficiency Strategic Plan
- 2012: Executive Order B-18-12 by Governor Brown
- 2015: SB350 – the most significant climate & clean energy legislation since AB32
  - Reduces GHG emission goals to 80% below 1990 levels by 2050
  - Building sector is a major target for emissions reductions

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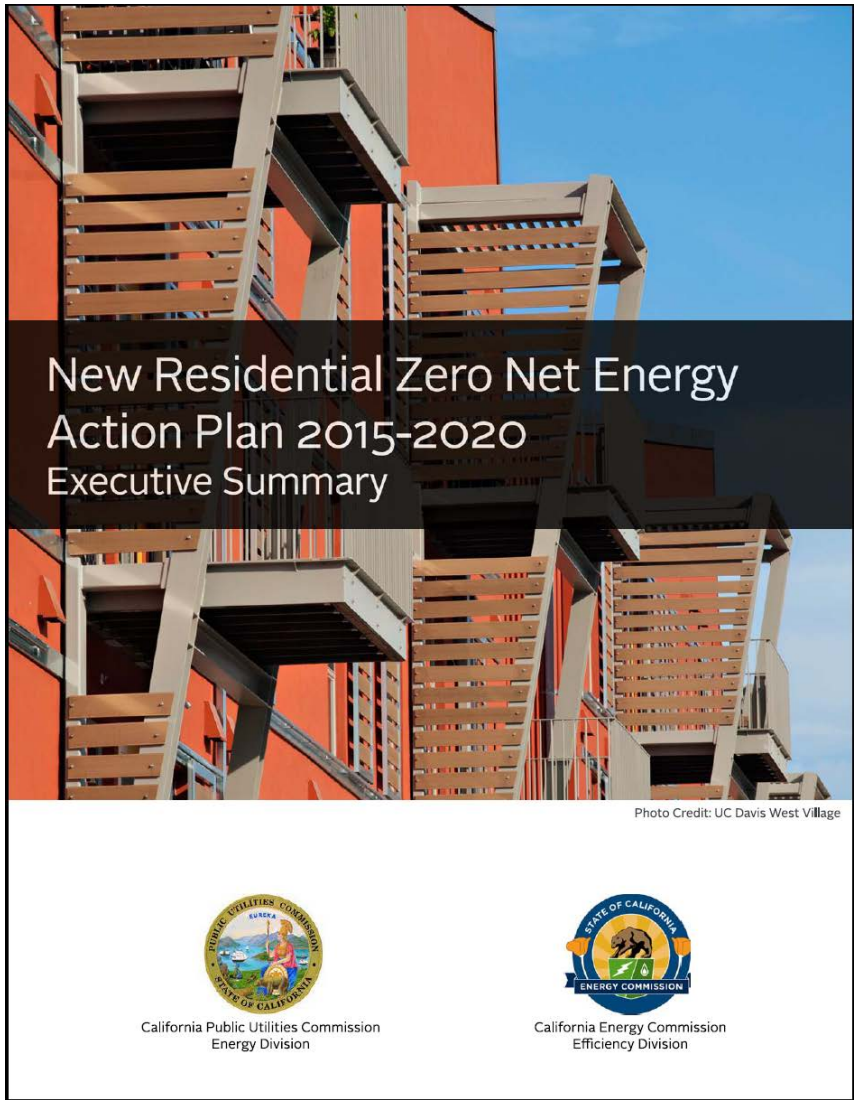
CPUC and CEC Action Plan 2015-2020



- Stated goal of 100% of new homes constructed to ZNE standard by 2020
- Development of a self-sustaining market for ZNE new homes
- Includes single-family and low-rise multi-family homes
- Implementation involves:
  - State agencies
  - Local governments
  - Utilities

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ZNE is Being Driven by the Energy Code

Each code update is designed to cost-effectively reduce the energy use of new homes by 1/3 or more.

- 2013 – effective July 2014
- 2016 – effective Jan 2017
- 2019 – effective Jan 2020
  - 2020 CA ZNE goal (established in 2006) to be *partially* met
  - Proposed 2019 code requires enough renewable energy to offset only the annual electricity for typical electric uses (*not* space or water heating, cooking, clothes drying)

Multifamily Note

Low-rise multifamily buildings (up to three stories) are included in the 2020 ZNE target. The State has set a 2030 ZNE target for high-rise residential buildings and commercial buildings.

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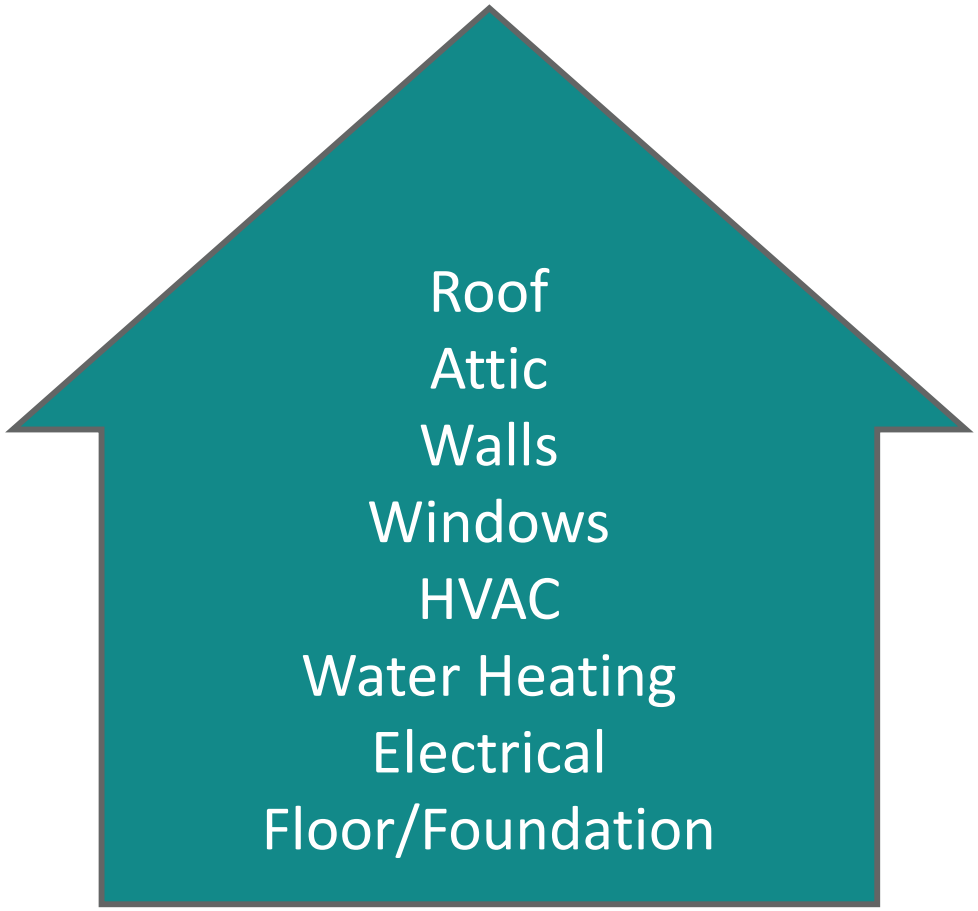
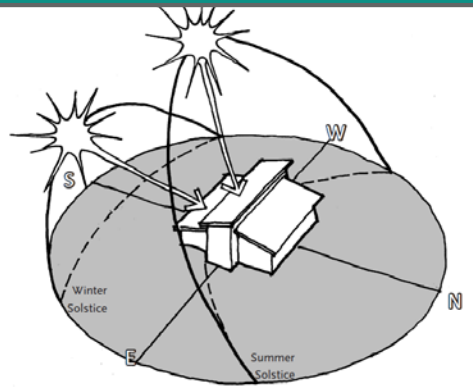
Features of ZNE Homes



Basic Ingredients of ZNE Homes

Efficient form & orientation



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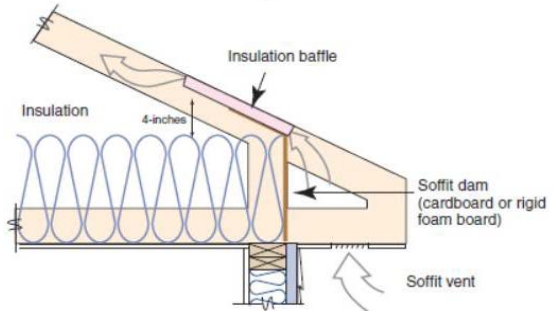
High performance enclosure



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Efficient mechanicals

+

Best-in-class electric loads

+

Renewable energy

=

ZERO

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Emerging Components of ZNE Homes

Performance dashboards

- Real-time data
- Actionable information

Electric vehicles

Battery storage

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ZNE Design Priorities

1. **Low/no-cost climatic design features**
   - Mostly south-facing windows with overhangs to block excess sun in summer
   - Windows on opposite sides of the house to provide cross-ventilation
   - Shade trees in warmer climates, especially on west side of the home

Photo credit: National Renewable Energy Laboratory

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ZNE Design Priorities

1. **Low/no-cost climatic design features**
2. **Minimize heating and cooling loads through efficient thermal envelope design**
   - High insulation levels (roof, walls, floor/foundation)
   - Well-sealed building envelope
   - High-performance windows

Multifamily Note

Envelope measures tend to be a lower priority in multifamily buildings, because there is less exposed surface area. Efficient heating, cooling, and water heating systems are often more important.

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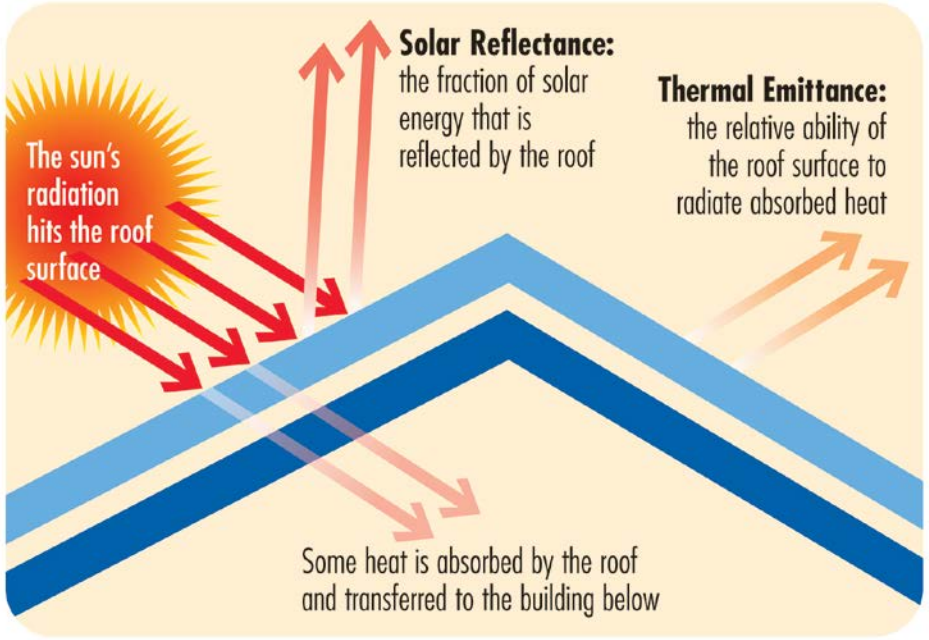
Cool Roofs Decrease Radiant Solar Gain

"Cool roofs" are beneficial in Climate Zone 2 (Santa Rosa) and 4, and required in Climate Zone 12. There is no net effect in Climate Zone 3.



COOL ROOF RATING COUNCIL ®
RATED PRODUCT

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High Performance Attic Options

(Title 24-2016 Prescriptive Requirement in Climate Zones 4 and 12)

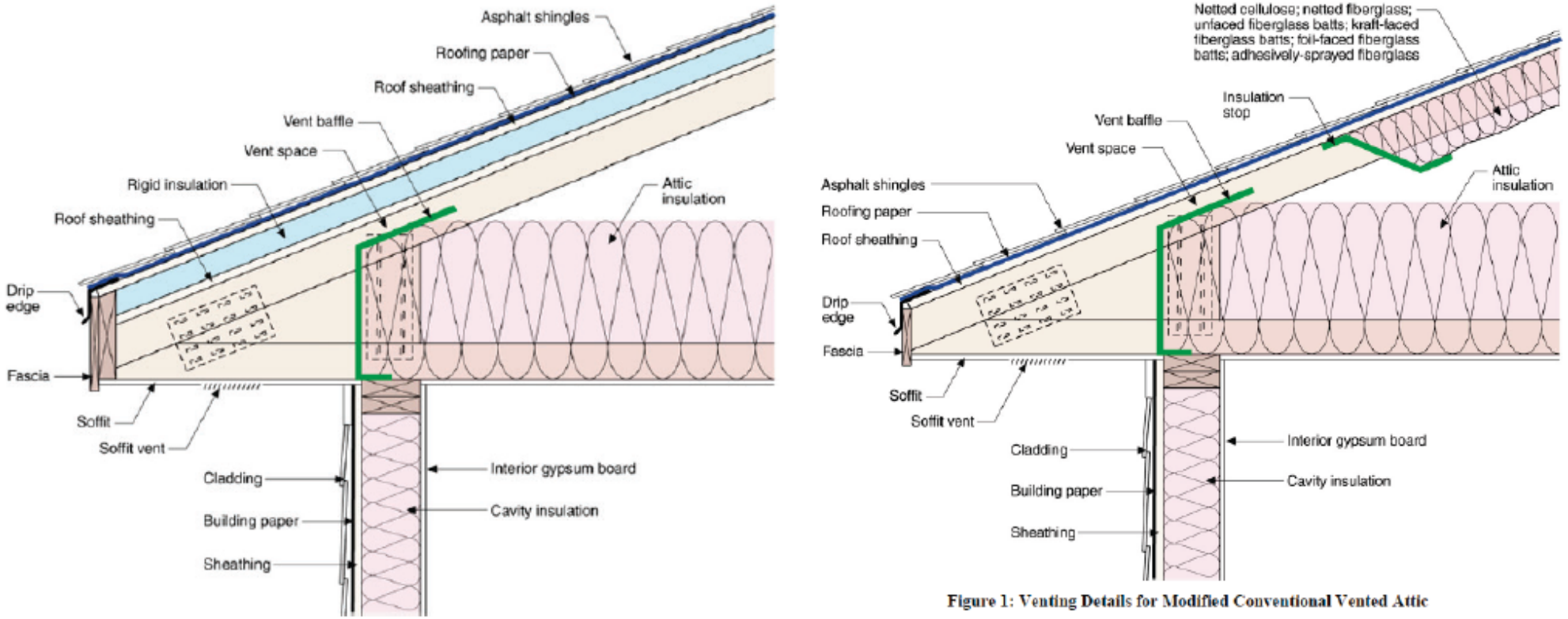


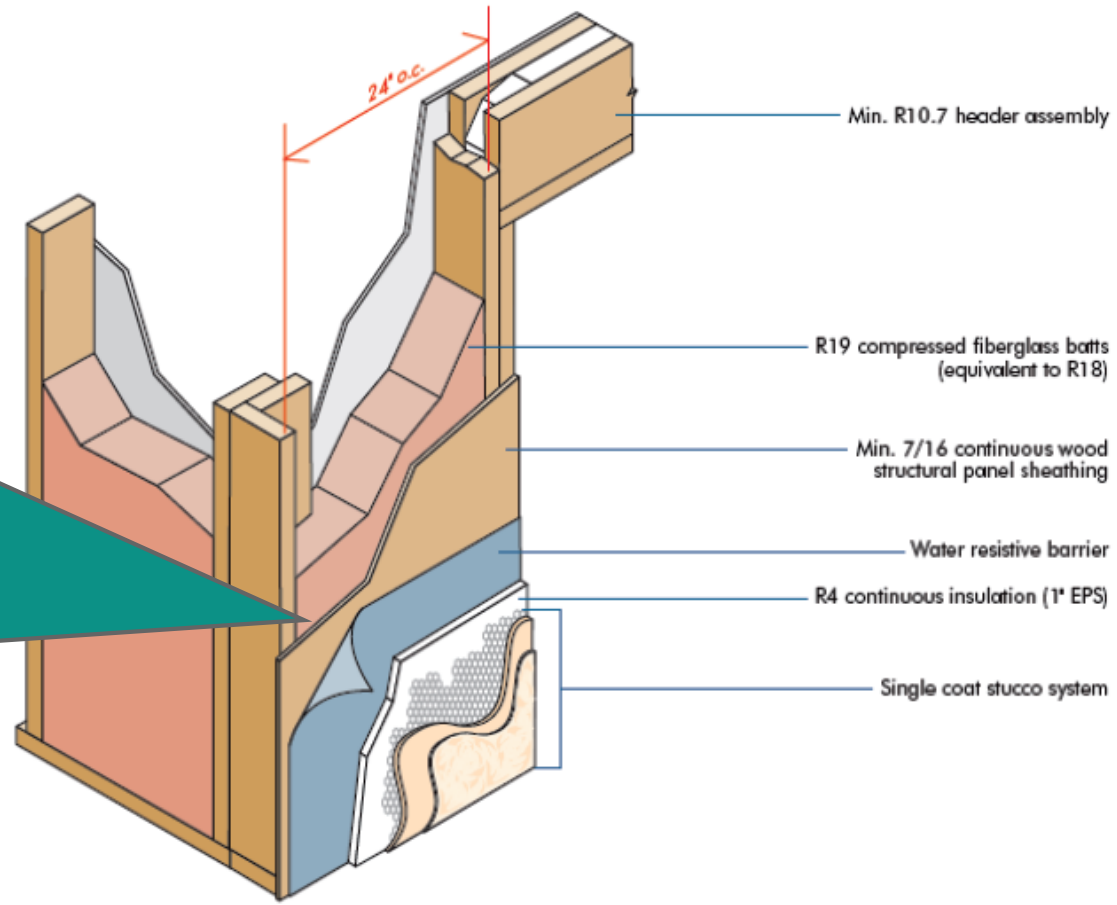
Figure 1: Venting Details for Modified Conventional Vented Attic

Source: Building Science Corporation

CEC 2016 Residential Compliance Manual p3-46.

Advanced Wall Framing

Insulation must be installed adjacent to an air barrier to effectively stop heat transfer



Source: APA, The Engineered Wood Association

CEC 2016 Residential Compliance Manual p3-76.

- 2x6 @ 24" o.c.
- R-19 insulation
- Reduced thermal bridging
- 3-stud corners
- R-4 exterior rigid
- R-7 header

(Assembly U-Factor = 0.051)

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Mandatory Air Sealing Requirement

All joints, penetrations and other openings in the building envelope that are potential sources of air leakage shall be caulked, gasketed, weather stripped, or otherwise sealed to limit infiltration and exfiltration.

(Title 24, Part 6, Section 110.7)

Possibly the most overlooked construction quality measure.
Has **major** impact on HVAC energy use

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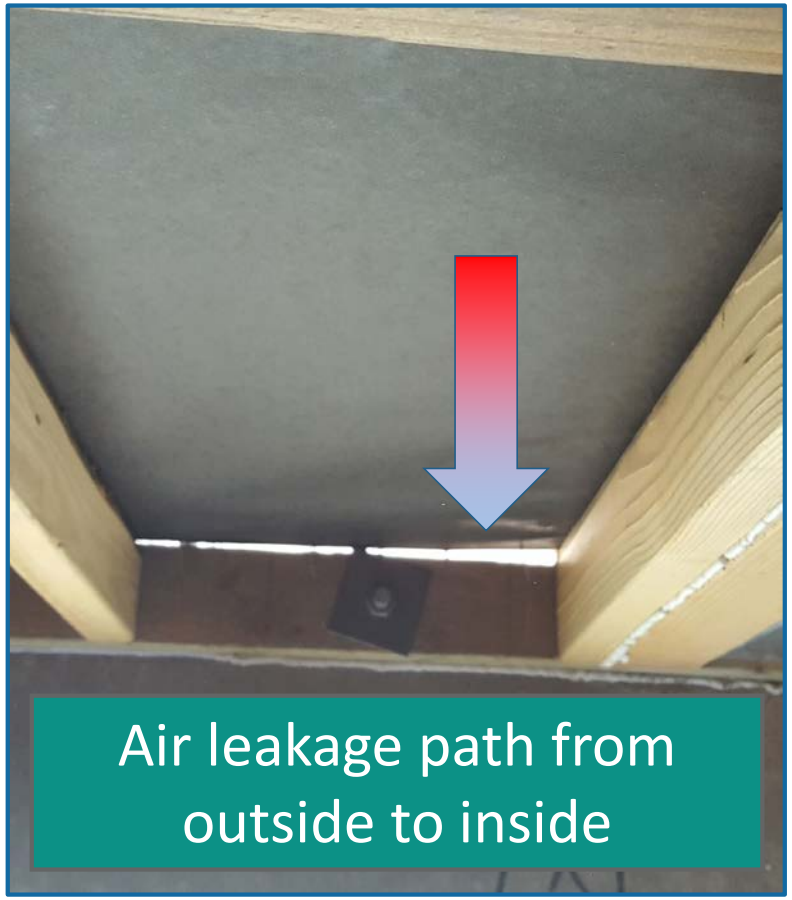
Common Air Sealing Problems



Air leakage path from outside to inside

No sealing or insulation behind tub

Uninsulated attic connected to living space

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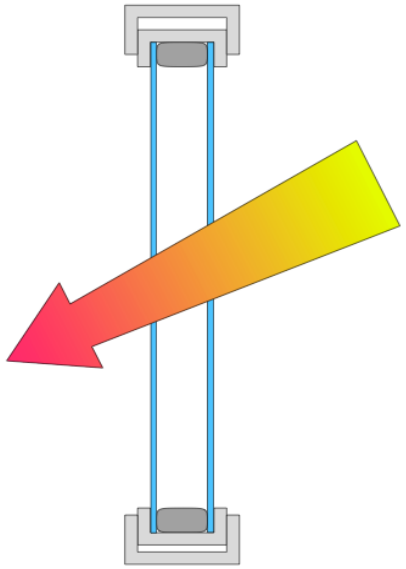
Windows are a Weak Point

Windows are a main source of heat transfer in a home through:

- Solar gains – direct sunlight passing through windows
  - Lower Solar Heat Gain Coefficient (SHGC) = less heat gain
- Conduction – thermal energy transferred through windows
  - Lower U-factor = less energy transfer



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ZNE Design Priorities

1. **Low/no-cost climatic design features**
2. **Minimize heating and cooling loads through efficient thermal envelope design**
3. **Minimize heating and cooling energy use**
   - Right-size equipment for reduced loads
   - Select energy efficient equipment
   - Install ducts in conditioned space and minimize leakage

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Locating HVAC Equipment & Ducts

Locate all HVAC equipment and ducts in “high performance attic” or conditioned space

- Beneficial in all climate zones
- Improved attic temperatures
- Less heat transfer through ducts and equipment
- Reduces size of HVAC equipment
- Decreases load on HVAC equipment
- Lowers utility bills

Multifamily Note

Although it is less common for ducts to be in attics in multifamily buildings, it is still important to ensure that they don’t pass through unconditioned spaces.

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HVAC and Title 24

Title 24 now **requires**:

- Load calculations
- System sizing
- Duct leakage verification

Designers can no longer use “rule of thumb” sizing

Other key factors:

- Sizing ducts to optimize airflow and minimize pressure drop
- Duct location, duct location, duct location
- Other HERS verifications are valuable

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ZNE Design Priorities

1. **Low/no-cost climatic design features**
2. **Minimize heating and cooling loads through efficient thermal envelope design**
3. **Minimize heating and cooling energy use**
4. **Minimize other energy uses**
   - Water heating
   - Ventilation
   - Lighting and electric loads

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Additional Measures to Help Reach ZNE

- Water heating
  - Choose a high Energy Factor (EF)
  - Design a compact layout
  - Consider drain water heat recovery
- Ventilation
  - Whole house fan can provide ventilation cooling
  - Heat or energy recovery in colder climates
- Lighting
- Appliances
- Electronics and other “plug loads”

Multifamily Note

Multifamily buildings may also have other energy loads such as corridor lighting, office equipment, laundry rooms, garage ventilation/lighting and elevators.

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More ZNE Benefits

- Improved comfort
- Lower risk of damage from moisture, UV light, other environmental sources
- Better indoor air quality (reduced natural gas combustion products, more consistent fresh air ventilation, reduced dust & pollen)
- Reduced noise from outside sources
- Shorter wait times for hot water
- Greater equipment reliability
- Security against rising cost of energy

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Renewable Energy Systems & Storage

Solar Electric Systems – Photovoltaics (PV)

- Solar PV provides the balance of electricity needed – after the home's energy use is at a minimum
- For adequate solar energy, we need to rethink our roof designs to allow the necessary space and orientation
- Designing a "solar roof" prior to construction is less expensive than tearing out an existing roof and retrofitting
- The solar array should be safely accessible for routine maintenance, such as cleaning the panels
- We should consider future needs, such as EV charging

Multifamily Note

Multi-family buildings often don't have enough roof space for PV to meet ZNE targets, and roof space may also be needed for other equipment. PVs may need to be located on the ground nearby or on parking structures.

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Energy Storage: Batteries

Household batteries:

- Store renewable electricity from excess PV production during low demand periods
- Reduce impact on grid by making stored energy available during demand peaks in late afternoon/early evening
- Are occupant-controlled
- Not yet found by the State to be cost-effective, but …
- May yield significant utility cost savings when combined with time-of-use rates

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Other Renewable Energy Options: Wind

Household-scale wind turbines

- Most viable for rural sites
  - Higher wind speeds
  - Fewer zoning restrictions
  - Reduced noise impact
- Average wind speed > 9 mph is desired
- Resource tends to be more intermittent and site-specific than solar
- Cost remains high (~$30K-$70K for a 10 kW turbine)
- Eligible for net metering

Small 10 kW wind turbine in Tehachapi, CA
(Photo credit: NREL)

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Examples of ZNE Homes

Cottle Zero Energy Home

- Location: San Jose, CA
- Builder: One Sky Homes
- Energy saving features:
  - Super-insulated walls
  - Tight enclosure (<0.6 ACH_{50})
  - Triple-pane windows
  - Heat recovery ventilation
  - Nighttime ventilation cooling
  - Energy Star appliances
  - Solar hot water
  - Solar PV system

Photo: One Sky Homes

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Mutual Housing at Spring Lake (62 units)

- Location: Woodland, CA
- Developer: Mutual Housing
- Affordable housing
- DOE Zero Energy Ready
- Energy saving features:
  - 3-function heat pumps
  - Heat pump water heater
  - High performance walls
  - Tightly sealed enclosures
  - Tightly sealed buried ducts
  - Solar PV systems

Photo: DOE / Mutual Housing

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ABC Green Home 3.0

- Location: Fullerton, CA
- Builder: Habitat for Humanity
- Energy saving features:
  - Conditioned attic
  - Advanced framing
  - Building control system
  - On-demand hot water
  - Solar PV system

Photo: Green Home Builder

PG&E Zero Net Energy Display House

- Location: Stockton, CA – PG&E Energy Training Center
- Educational displays inform visitors about energy efficiency practices and technologies
- Promotes PV, water conservation, electric vehicles
- Includes interactive dashboard comparing energy use of ZNE with code-minimum homes

VIDEO: http://www.pgecurrents.com/2016/06/01/video-pge-helps-lead-effort-toward-clean-energy-building-solutions/

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Keys to Success with ZNE

Planning
+ Design
+ Workmanship
+ Verification

ZNE Success

Keys to Success: Planning

Integrated Project Delivery (IPD)

- Includes installation trades and verifiers on your project team
- Set common goals for team
- Make sure trades are properly trained
- Monitor job progress
- Verify performance throughout construction
- Take advantage of incentives and rebates

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Keys to Success: Design

- Reach for the 2019 code or above
- Choose high-quality, defect-resistant insulation (blown, not batts)
- Provide air-sealing specifications, cross-section, and details
- Accommodate HVAC equipment in conditioned space
- Design compact layouts for HVAC and hot water
- Design roof to meet solar PV needs

Keys to Success: Construction

- Set performance expectations early with the entire construction crew
  - Provide education to avoid common pitfalls
- Meet Quality Insulation Installation (QII) requirements
- Build the envelope tight – air-seal thoroughly
  - Do a blower door test at the earliest opportunity
- Install right-sized, efficient HVAC equipment
- Maintain a rigorous quality management program

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Keys to Success: Verification

Check as-built details against plans – ensure full compliance

- Air barriers must be in place
- Air sealing must be comprehensive
- Advanced wall framing must match plan specs
- Window NFRC stickers must match
- Insulation must be properly installed & contact all 6 sides of cavities
- QII must be HERS verified
- HVAC requires proper load calculations and duct design
- All lighting to be light-emitting diode (LED)

Incentives & Resources for ZNE

Incentives:

- Energy Upgrade CA (EUC) https://energyupgradeca.org/en/
- New Solar Homes Partnership (NSHP) http://www.gosolarcalifornia.org/about/nshp.php
- California Advanced Homes Program (CAHP) http://cahp-pge.com/masterbuilder/
- California Multifamily New Homes Program (CMFNH) http://cmfnh.com/
- Savings by Design http://www.savingsbydesign.com/

Resources:

- New Residential Zero Net Energy Action Plan 2015-2020
- http://www.californiaznehomes.com/faq
- http://netzeroenergycoalition.com/
- https://energycodeace.com/

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Thank you for attending!

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