TRI-COUNTY
REGIONAL ENERGY NETWORK
SAN LUIS OBISPO • SANTA BARBARA • VENTURA

Next Generation Passive Solar

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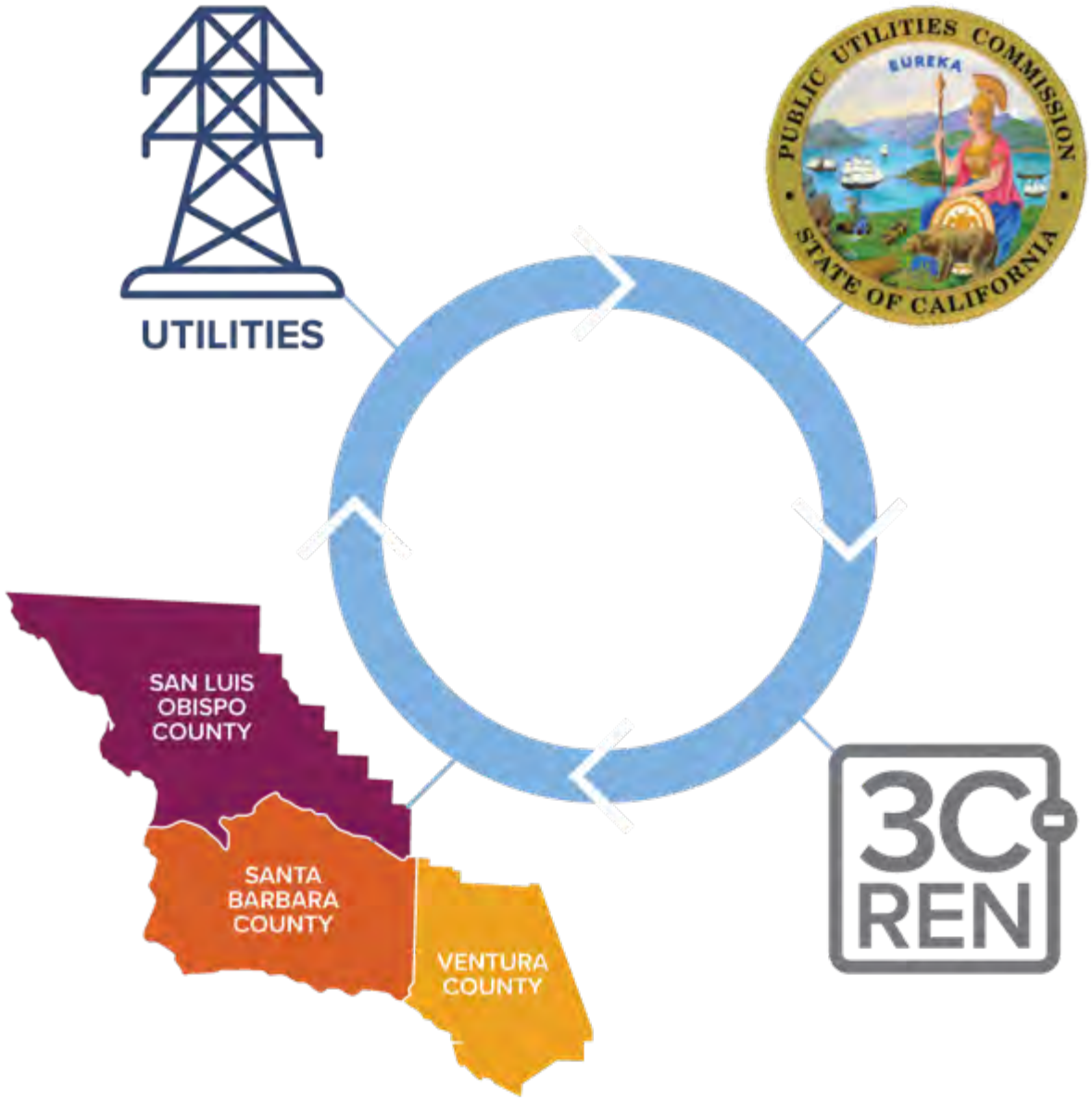
September 23, 2025

Before We Begin

Here are some quick reminders:

- Call in? Please **share** full name to confirm attendance
- To receive AIA LUs, you **must attend** at least 80% of the training. Attendance will be verified
- Use the "**Chat**“ to share questions or comments
- Slides/recording are **shared** after most events and can be found on 3C-REN's on-demand page
- 3C-REN does **not** allow **AI notetakers**, unless used to accommodate a disability



Tri-County Regional Energy Network

3C-REN is a collaboration between the tri-counties

Our programs reduce energy use for a more sustainable, equitable and economically vibrant Central Coast

Our free services are funded via the CPUC, bringing ratepayer dollars back to the region

Today’s Learning Objectives

- Review passive thermal design strategies including basic climate analysis and guidelines for orientation, fenestration and thermal mass.
- Understand current science relating to the impacts of daylight and views on occupant health and learn best practices for right-sizing windows and skylights, managing glare and selecting appropriate visible light transmittance.
- Learn strategies to develop an integrated system for ventilation, optimizing passive systems (operable windows and skylights, stack effect, cross ventilation) with mechanical systems
- Review a case study to integrate passive thermal design with a high-performance envelope.

Learning Units:

- 1.0 AIA HSW LU approved for this course
- 1.0 CAB ZNCD

Agenda

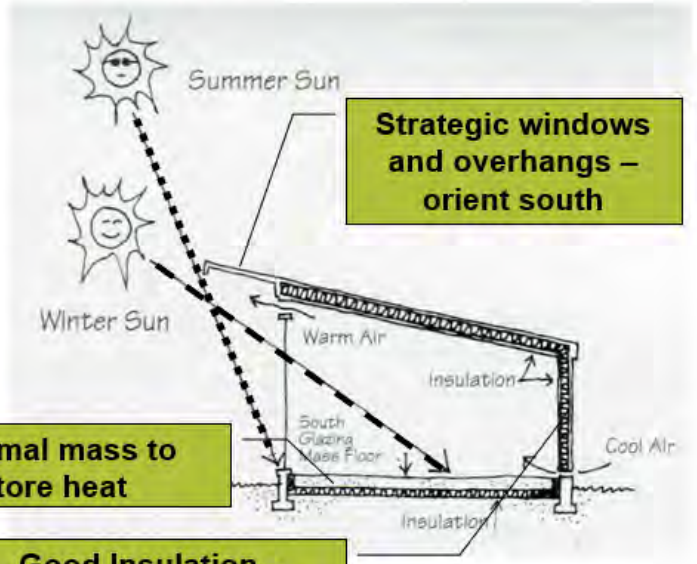
1. Historic Context
2. Passive Solar Principles, circa 2000
3. What’s Changed
4. What Works Now
5. What’s Next

But first… Why this class?

Passive Thermal Design

OIVM not OIL*

- O – Orientation
- I – Insulation
- V – Ventilation
- M - Mass



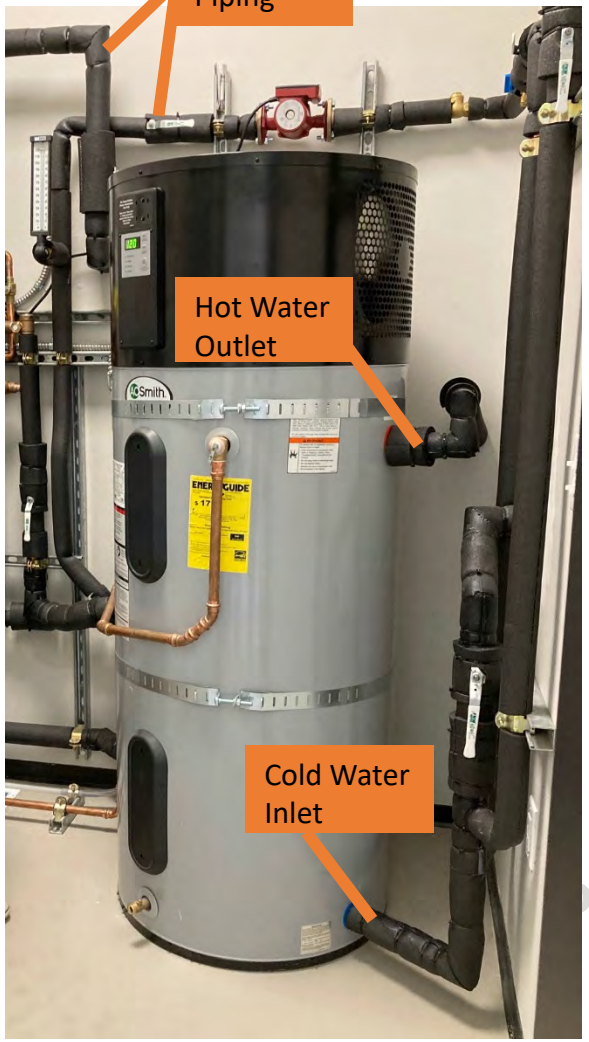
Strategic windows and overhangs – orient south

Thermal mass to store heat

Good Insulation – R-19+ walls, R-30+ roof

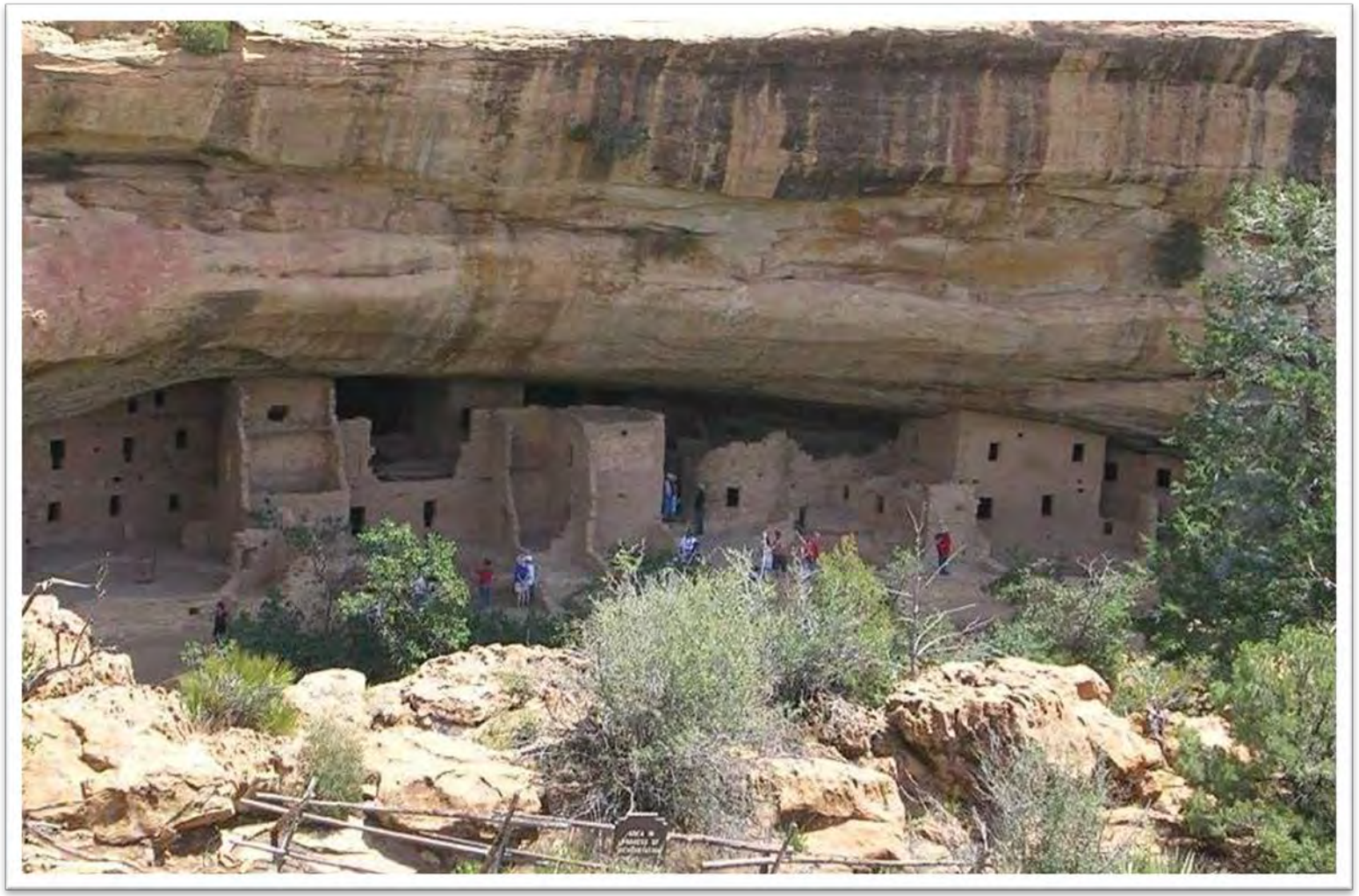
*Credit to Turko Semmes

?



Historic Context

Millennia of Climate-Responsive Design



Collective Amnesia, Unleashed creativity and/or Hubris

United Nations Building – Le Corbusier

"Glass House" – Philip Johnson

12,000 SF "Modern Farmhouse"

National Energy Crisis and the Oil Embargo

- Oil Embargo in 1973
  - US dependent on OPEC oil
  - Crisis from limited supply of gas
- The embargo helped to change attitude towards energy
  - Speed limit from 70 to 55 mph to save energy
  - Oregon turned off all hot water to state buildings

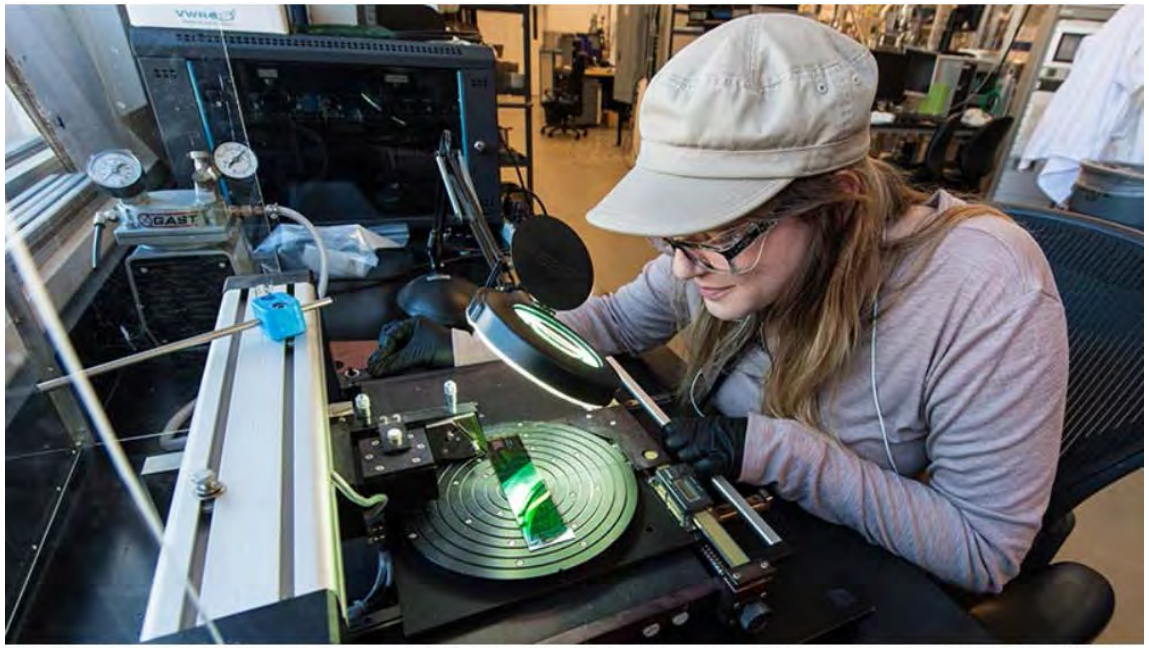
Photos: theconversation.com, https://history.state.gov/milestones/1969-1976/oil-embargo

Solar Energy and Building Energy Efficiency

- Established in 1974, National Renewable Energy Laboratory (NREL) began operating in 1977 as the Solar Energy Research Institute.

- President Carter signs the Solar Photovoltaic Energy Research, Development, and Demonstration Act of 1978 with a goal of getting solar cells to $1/watt by 1987.

- California Buildings Standards Commission created the CA Energy Code in 1978
  - To reduce CA energy consumption
  - Development of California Energy Efficiency Standards



Using NREL's state-of-the-art facilities, a scientist scribes an organic photovoltaic module to make into a sample to test in a solar simulator. *Photo by Dennis Schroeder, NREL*

Image Source: www.nrel.gov

Why *Passive* Solar for the General Customer?

- Occupant Comfort
- Save Money and Energy
- Self-reliance / Energy Independence
- Status – Style and Aesthetics

Big Strategy:

Building efficiency and passive solar first, then implement active solar (PV).

Stern House

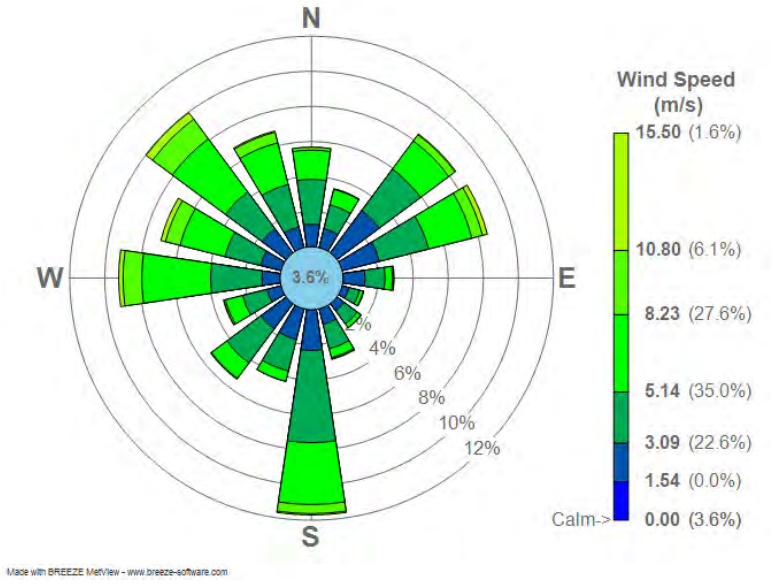
Bruce Severance

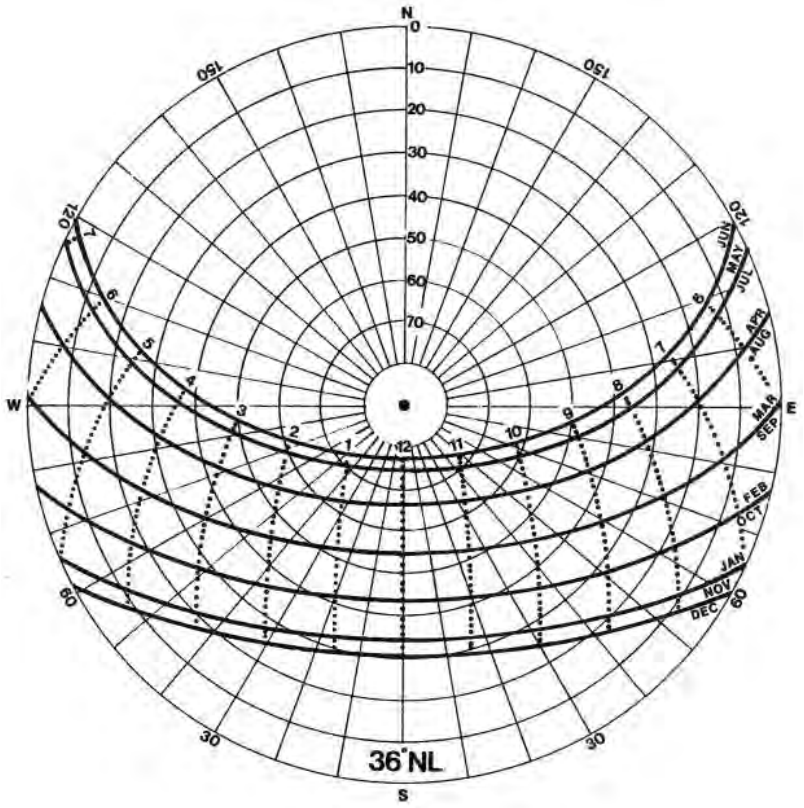
- Orientation for passive solar and PV
- Designed for Zero Net Energy (ZNE) and occupant comfort
- Used phase change material (PCM)

Passive Solar Principles

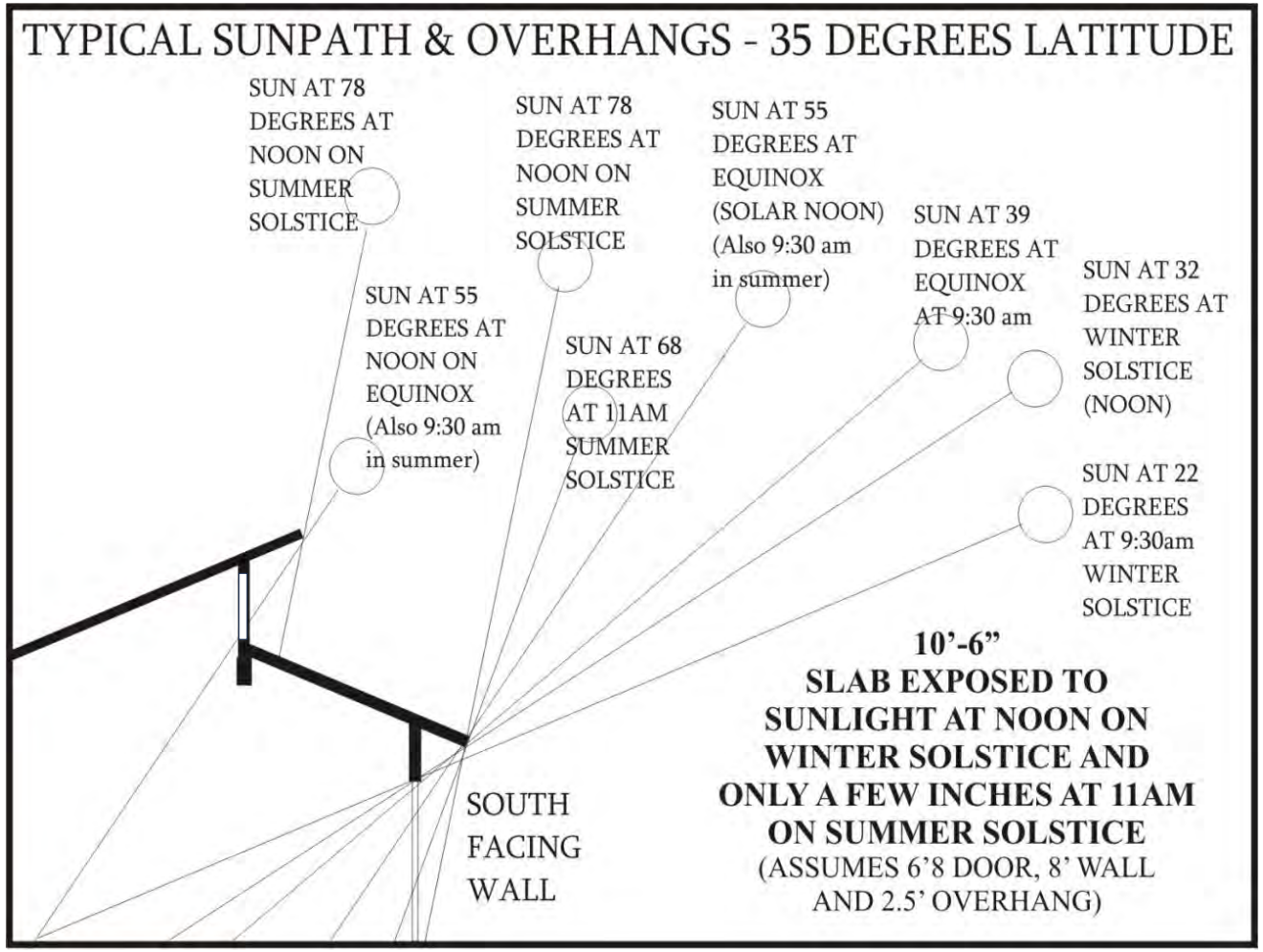
Site-Responsive Design

- Solar geometry
- Heating or cooling load dominated
- Occupant or Envelope load dominated
- Wind Rose





Site-Responsive Design –Designing for Sun Exposure



Affordable Energy Efficiency by Semmes & Company Builders and In Balance Green Consulting

Orientation, Windows and Thermal Mass

Example:

Congregation Beth David, SLO

- South-facing
- Strawbale & Mass
- Overhangs
- Trombe walls

Architect: San Luis Sustainability Group

Natural Ventilation –Operable Windows and Cooling Towers

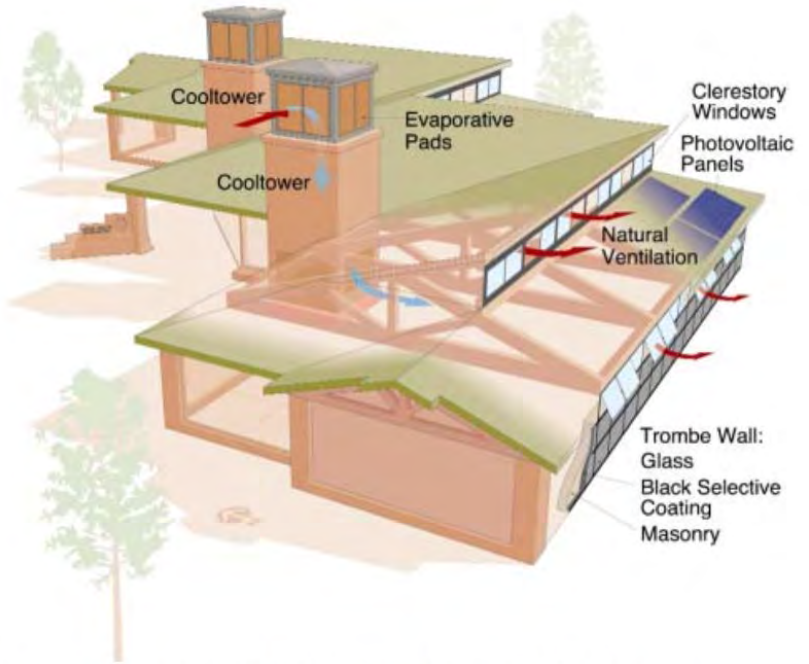


Figure 4-2 As-built Zion layout and energy-efficient features

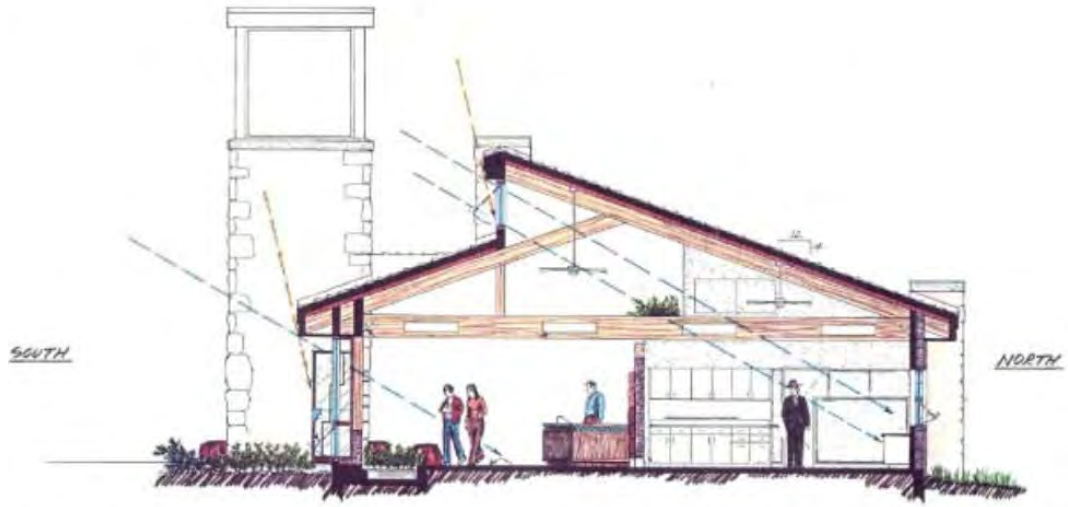
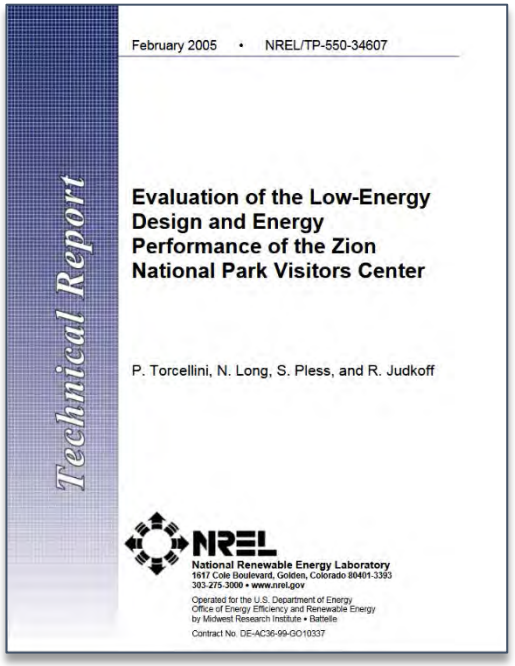
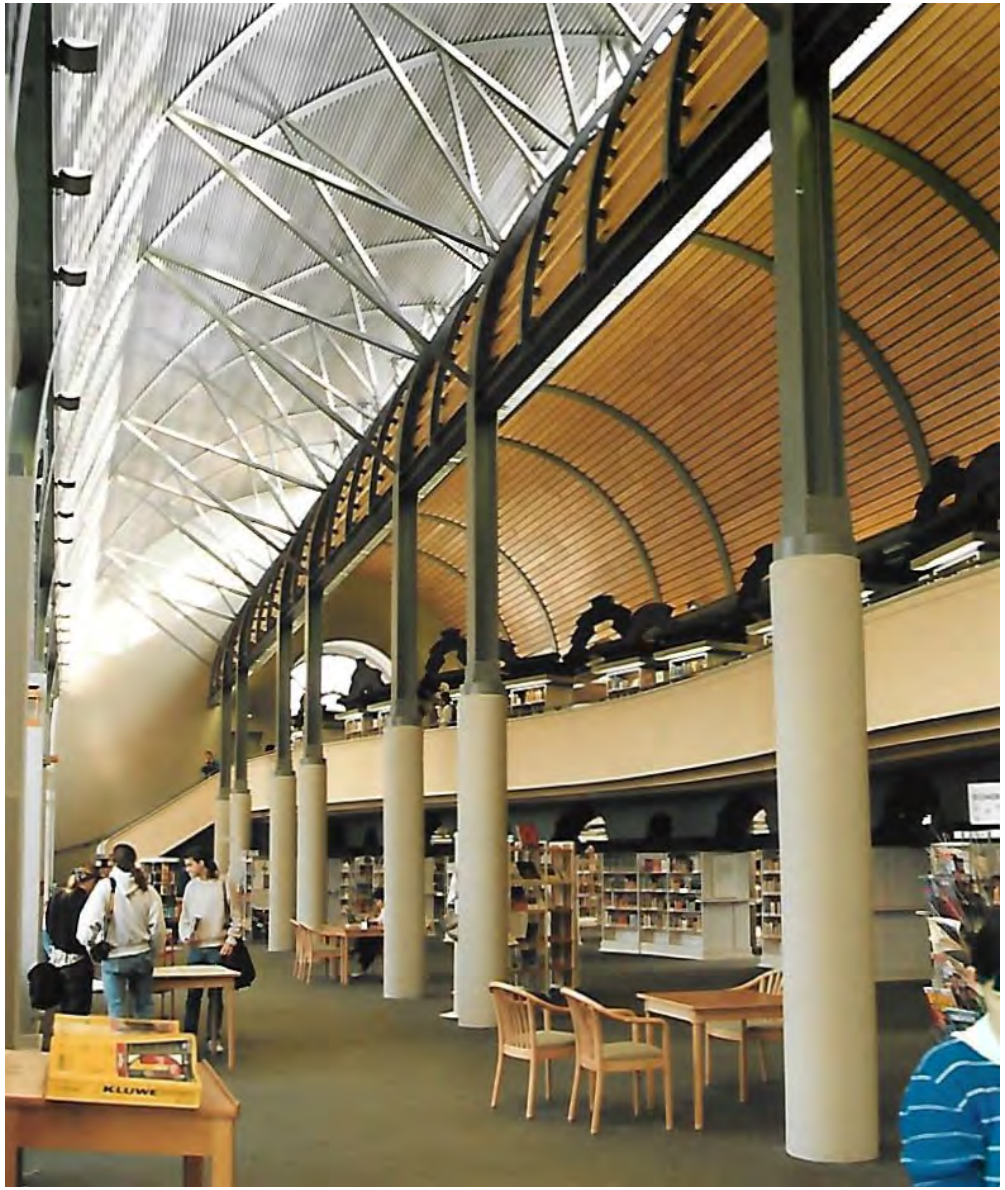


Figure 3-6 Diagram of energy design solutions for the Visitor Center Complex

Figure 4-17 Interior view of a cooltower showing operable shutters that allow cool air to enter the building through the bottom louvers



Balanced Daylight and Integrated Electrical Light



Humbolt-Bibliothek
Built 1987-1989
Architect Charles Moore

What Changed?

Climate Data, Computer Modeling and Title 24 Cost Effectiveness

- Performance Based Computer Energy Modeling
- CEC had to show ‘cost effectiveness’ which took into account source energy
- Climate Data evolved based on empirical evidence
- The T24 Baseline ‘caught-up’ to passive-solar and energy efficiency high-performance construction

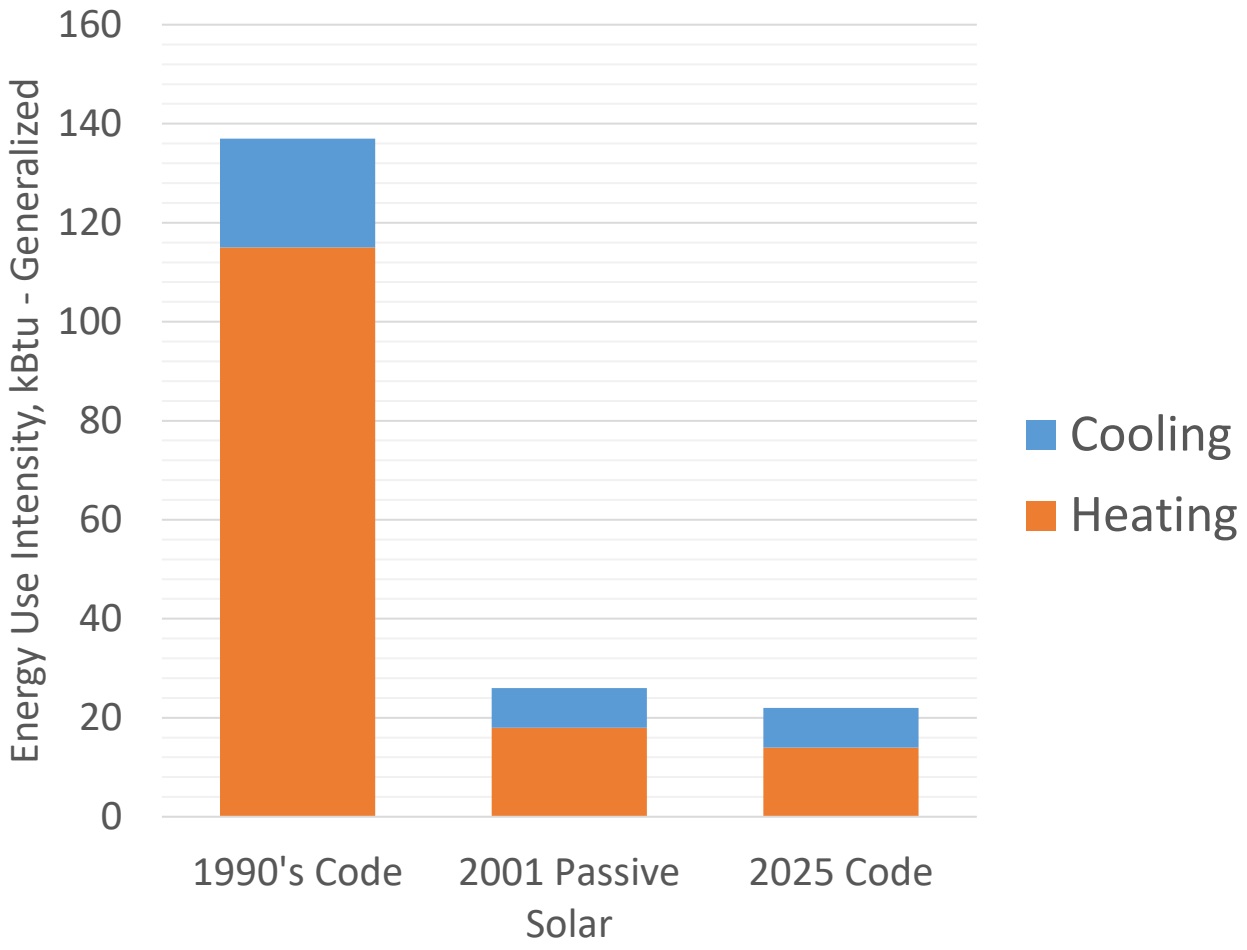
CERTIFICATE OF COMPLIANCE - LOWRISE MULTIFAMILY MIXED USE PERFORMANCE COMPLIANCE METHOD	LMCC-PRF-01-E
Lowrise Multifamily Mixed Use Performance Compliance Method	(Page 4 of 31)

C2. TDV ENERGY COMPLIANCE RESULTS FOR PERFORMANCE COMPONENTS (Annual TDV Energy Use, kBtu/ft^2 - yr)

	COMPLIES[2]		
Energy Component	Standard Design (TDV)	Proposed Design (TDV)	Compliance Margin (TDV)[1]
Space Heating	3.06	5.15	-2.09
Space Cooling	11.66	10.33	1.33
Indoor Fans	24.86	18.77	6.09
Heat Rejection	0	0	0
Pumps & Misc.	0.34	0.61	-0.27
Domestic Hot Water	81.3	77.52	3.78
Indoor Lighting	23.52	16.89	6.63
Flexibility	---	---	---
EFFICIENCY COMPLIANCE TOTAL	**144.74**	**129.27**	**15.47 (10.7%)**
Photovoltaics	-96.8	-154.34	57.54
Batteries	---	-57.72	57.72
TOTAL COMPLIANCE	**47.94**	**-82.79**	**130.73 (272.7%)**

[1] *Notes: This number in parenthesis following the Compliance Margin in column 4, represents the Percent Better than Standard.*

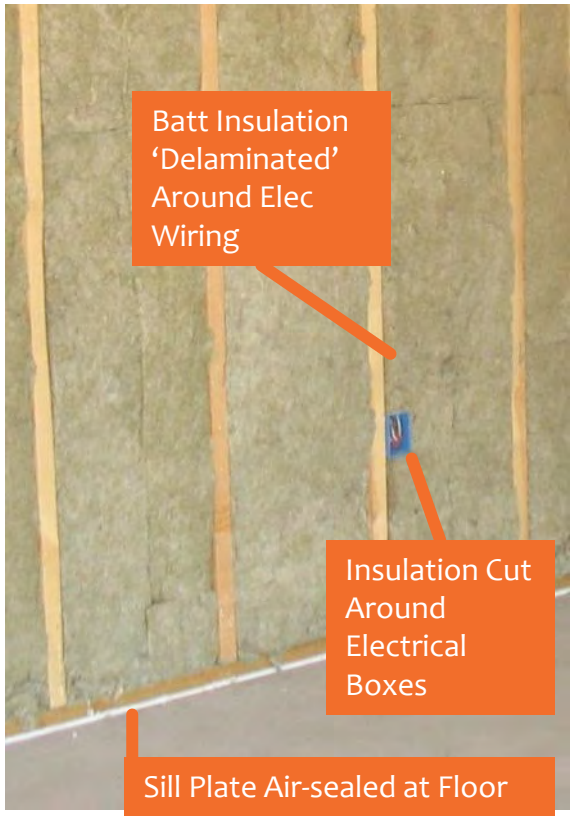
Dramatic Savings from 20 years ago – Now Code Baseline



- 1990's Home: Raised floor, concrete block exterior walls
- 2001 Passive Home: Add rigid insulation, R-54 ceiling, R-30 Floor, Low-e windows, Exterior Sunshades
- 2025 code: R-21 with Rigid, R-38 Roof, SOG, Low-e windows

Better Insulation and Better *Installation* Required

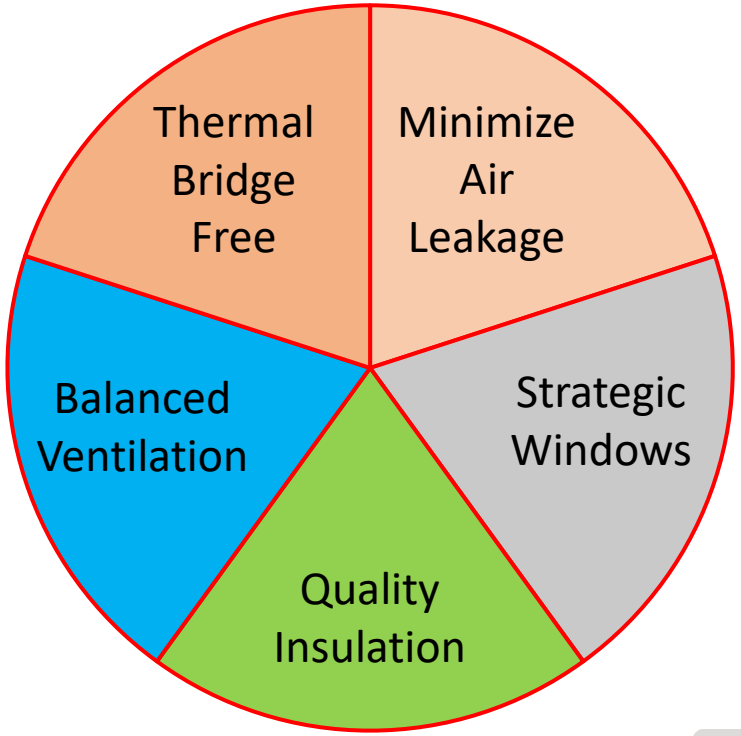
- New Insulation Materials and Standardized Testing
- Higher R-values
- QII and HERS Introduced into the Code



Blow-in Products fill the whole wall cavity. No Gaps – No Voids.

Passive Haus / Passive House

1. Quality Envelope Assemblies:
   i. High Quality Insulation
   ii. Thermal Bridging Eliminated
   iii. Air Leakage Minimized
2. Strategically Placed Quality Windows
3. Balanced Ventilation (IAQ) System
4. Energy Efficient HVAC, DHW and Appliances
5. Solar PV and Battery Storage



Thermal Mass vs Cost Benefit

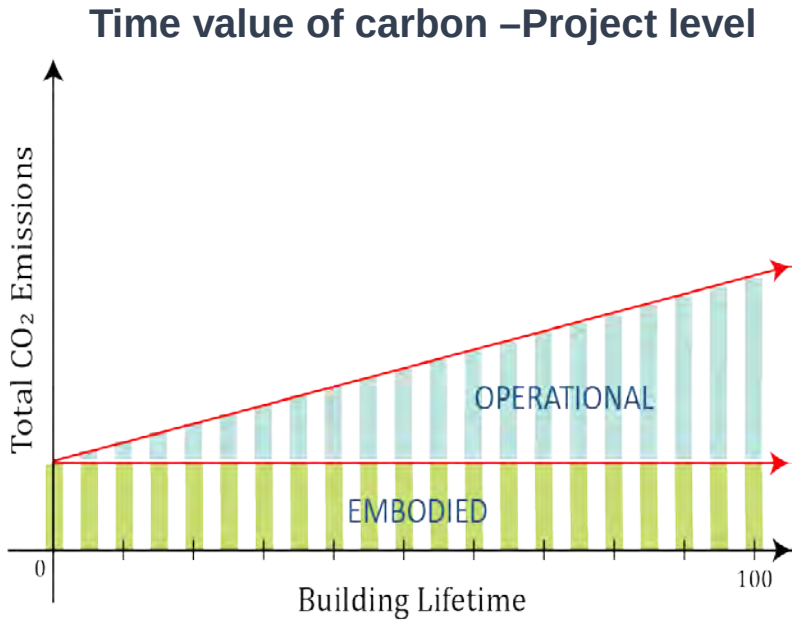
- Thermal Mass –provides heat storage and stabilizes interior temperatures
- Increasing cost of construction, i.e. more expensive than wood studs, with drywall.

“Over Massed” and Embodied Carbon Impact Discussions

Strawbale or Thick-Wall Assemblies with Stucco Exterior and “Real Plaster” Interiors

Solid Grout CMU Walls; Alternate - Rammed Earth

Exposed Mass Floors: Concrete or Adobe



Embodied carbon makes up the majority of carbon associated with a building in the first 20 years.

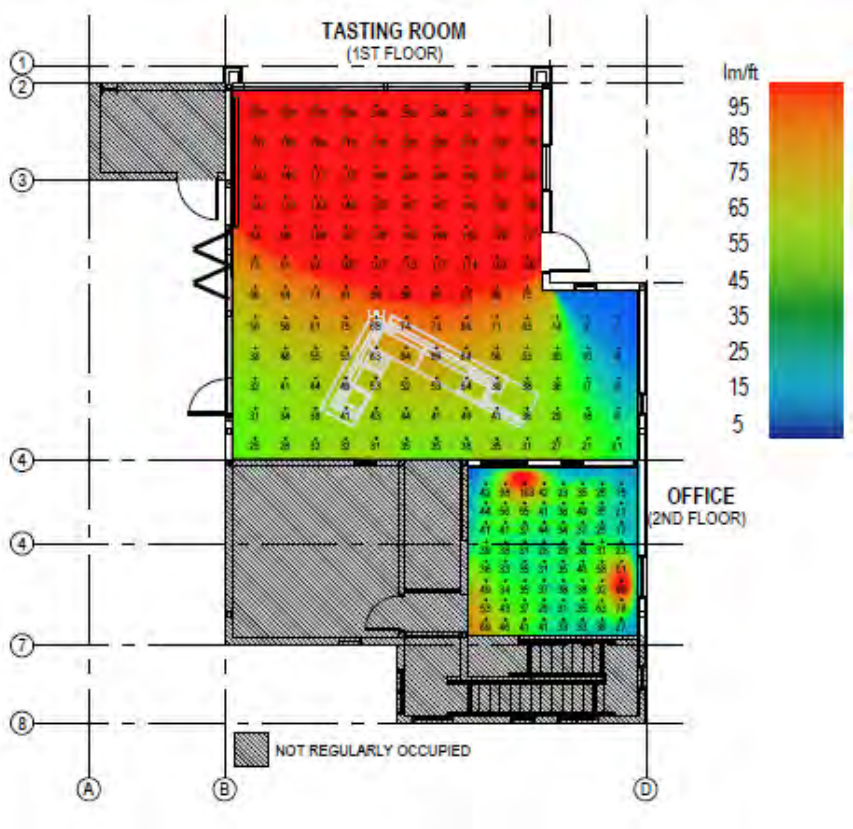
New and Improved Technology

- Greater lighting efficacy
- ‘High-performance’ windows
- Better insulation and air-sealing
- Higher efficiency HVAC and DHW
- Thermal mass benefit vs embodied carbon impacts
- Affordable high-efficiency heat pumps
- Affordable solar electric (PV) panels
- State-wide shift from fossil fuel to renewable energy

200w to 27w is 86.5% reduction in energy use

High Performance Windows and Daylighting Modeling

- Daylight Modeling and Glare Analysis
- High Performance Dual paned Low-e
- Specialty Glazing
- Optimized visible light transmittance



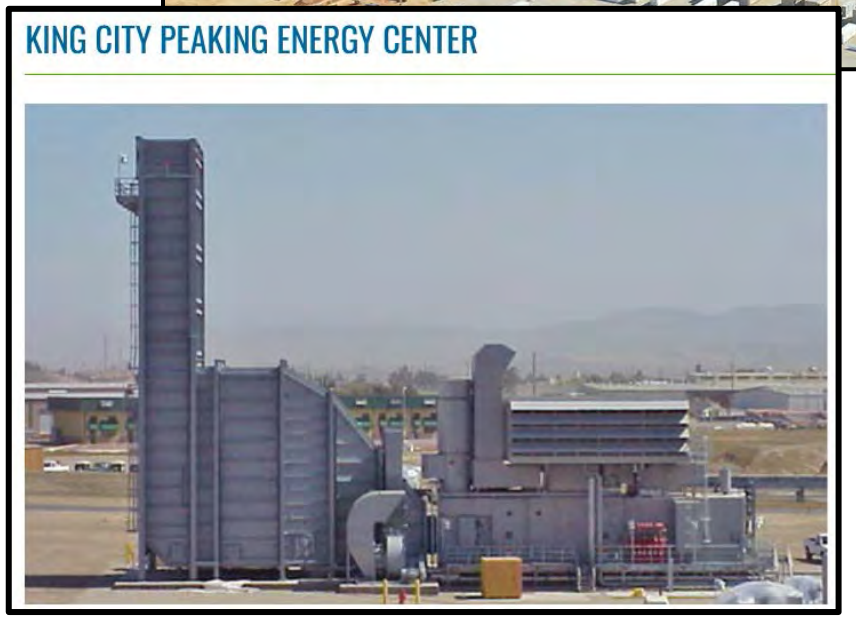
Shale Oak Winery, Paso Robles
Architect: Studio 2G

The Electric Grid in California Continues to Add Solar

- The cost of PV (Solar Cells) came down – affordability
- The electric grid in Western Region moved to renewable energy sources – now the grid is more than 60% non-fossil fuels
- Battery Energy Storage Systems can be rolled out on a grid-scale
- Fossil fuel plants provide only peak time of use

Edwards & Sanborn Solar and Energy Storage, Kern County, CA

https://www.mortenson.com/projects/edwards-sanborn-solar-plus-storage

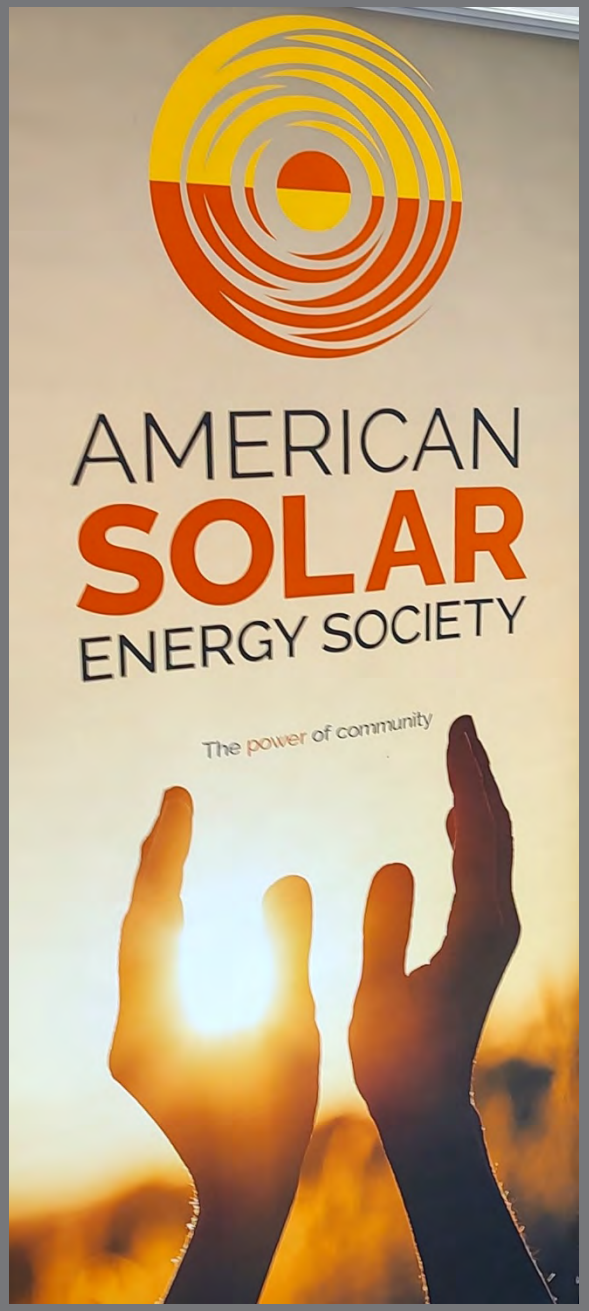


https://www.calpine.com/King-City-Peaking-Energy-Center

The Switch from Direct Combustion Fuel to Electric Heat Pumps, Electric and Induction Appliances

- The cost of PV (Solar Cells) came down –Affordable for individual owners –And Title 24 Prescriptive
- Electric heat pump technology became much more affordable and efficient (and, recently, refrigerants with lower GWP mandated)
- Induction cooking is more common and affordable

What Works Now?



Author, Architect and ASES Fellow: Solar Still Works!

Climate Analysis 2.0

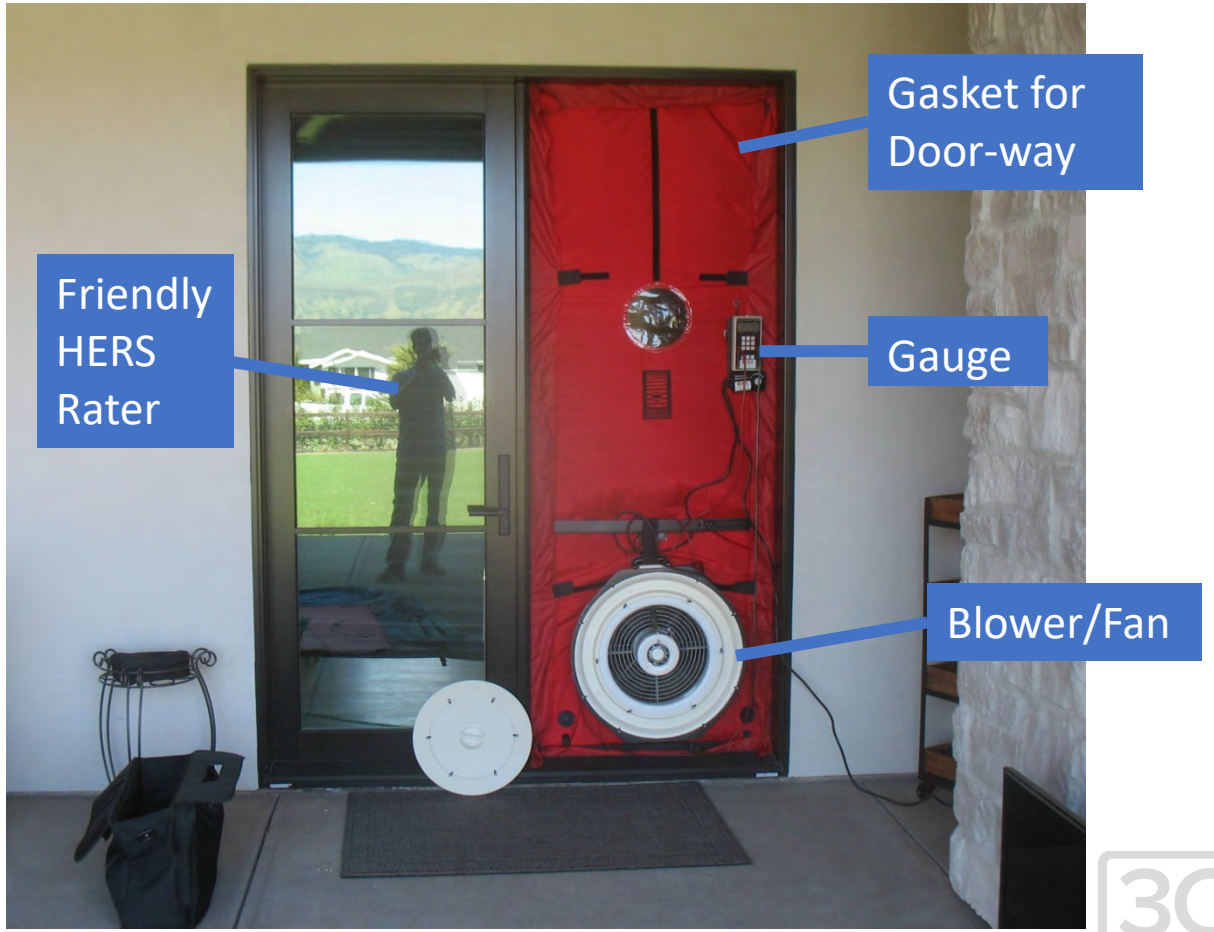
- Recognize and Anticipate Climate Change
- Integrated into building models, CAD programs, compliance software, PVWatts
- Know your climate zone, and implications
- HDD, CDD
- Diurnal swings
- Tradeoffs for heating, cooling

https://caenergy.maps.arcgis.com/apps/webappviewer/index.html?id=5cfefd9798214bea91cc4fddaa7e643f

Published climate data sets available from ASHRAE, NOAA, NREL, etc.

Envelope Matters

- Strategic amounts of insulation
- Air sealing, w/ verification – Blower Door Testing x2 or x3
- Reduce thermal bridging, Continuous Exterior Insulation
- Low-embodied carbon / biobased materials



Windows

- Orientation: Majority of window area is south facing
- Dual or triples paned? We recommend pricing out 6 – 10 packages
  - Many brands offer high performance triple paned units for the same price or less than dual paned units of other brands.

ASES Solar Homes Tour 2025 –Existing Home retro-fit for ZNE includes triple paned windows.

Windows

- Climate-specific U-factor and SHGC
  - Hot? LOW U-factor and low SHGC, i.e. SHGC-0.23 for CZ 4, 6-9
  - Cold? LOW U-factor and higher SHGC, i.e. SHGC-0.35 for CZ 5
  - Consider Visible Light Transmittance (Tvis) Typically higher the better. Target Tvis-0.3-0.6
- Start with Passive Solar guidelines ratio for window sizing: Window area as % of floor area

ThinGlass Triple Center of Glass Performance		
COATING	U-FACTOR	SHGC
SolarControl-6 TGT	0.12	0.25
Balanced-6 TGT	0.12	0.35
HighGain-6 TGT	0.13	0.57

ALPEN

3C REN

Windows – Passive Solar Guidelines

Assumes Slab on Grade (SOG) Construction for Thermal Mass

Ratio for window sizing; Window area as a % of floor area.

3C-REN Area (**CZ's 4 & 5**):

- **North 3-5%**
- **East 3-5%**
- **South target 20-24%**
- **West 0-2%**
- **Total 25-35%**

T24 Prescriptive is 20% Total

3C-REN Area (**CZ's 6**):

- **North 3-5%**
- **East 3-5%**
- **South target 15-22%**
- **West 0-2%**
- **Total 24-30%**

T24 Prescriptive is 20% Total and 5% max West

3C-REN Area (**CZ's 9**):

- **North 3-5%**
- **East 3-5%**
- **South target 10-15%**
- **West 0-2%**
- **Total 16-24%**

T24 Prescriptive is 20% Total and 5% max West

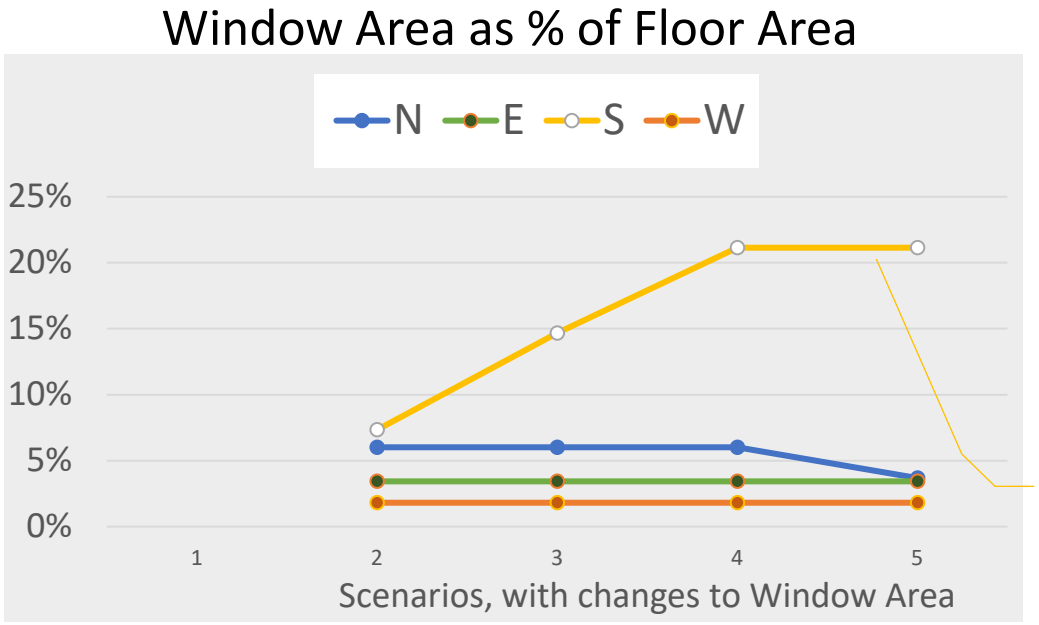
Note: Use the T24 2025 update U-factor and SHGC as a starting point.

CZ 4: U-0.27 and SHGC-0.23 **CZ 5**: U-0.27 and SHGC-0.35 **CZ 6-9:** U-0.30 and SHGC-0.23

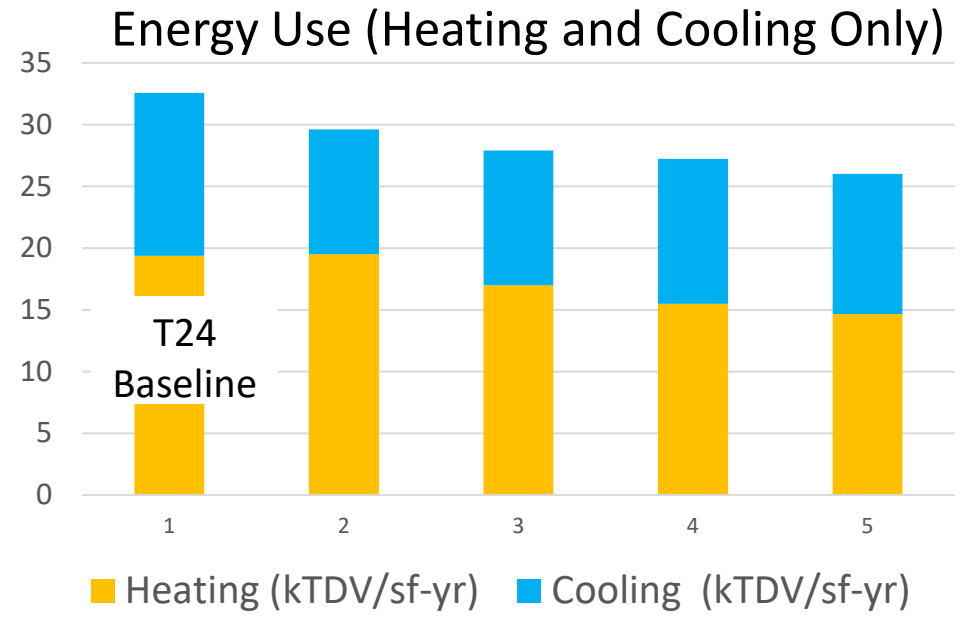
In all scenarios a lower U-factor will be significantly better.

Residential Window Analysis Climate Zone 4

CZ 4 - 2100sf Slab on Grade, R-21+R-5 Envelope, SHGC-0.23



Maximized south window area



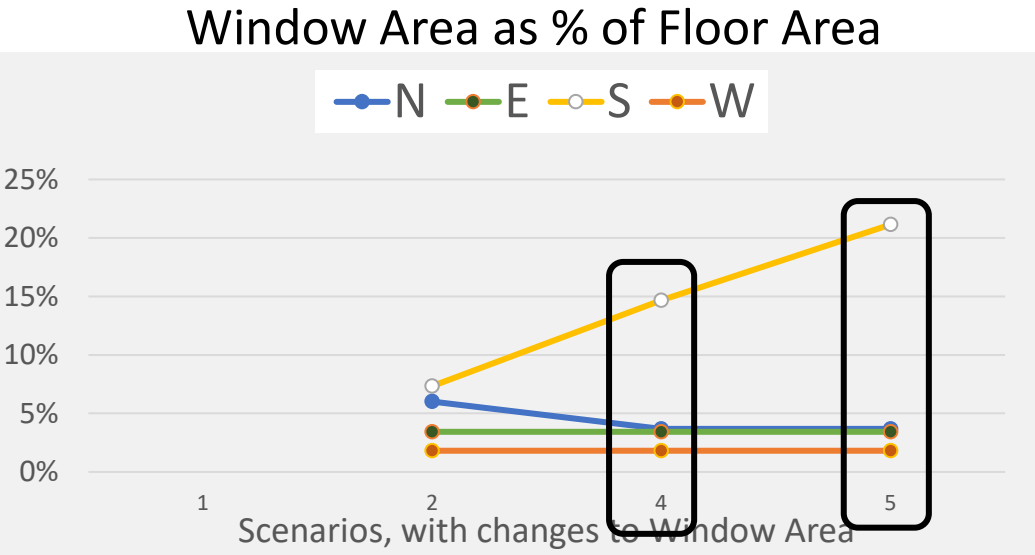
Space conditioning energy use decreases as south window increases, and non-south decreases

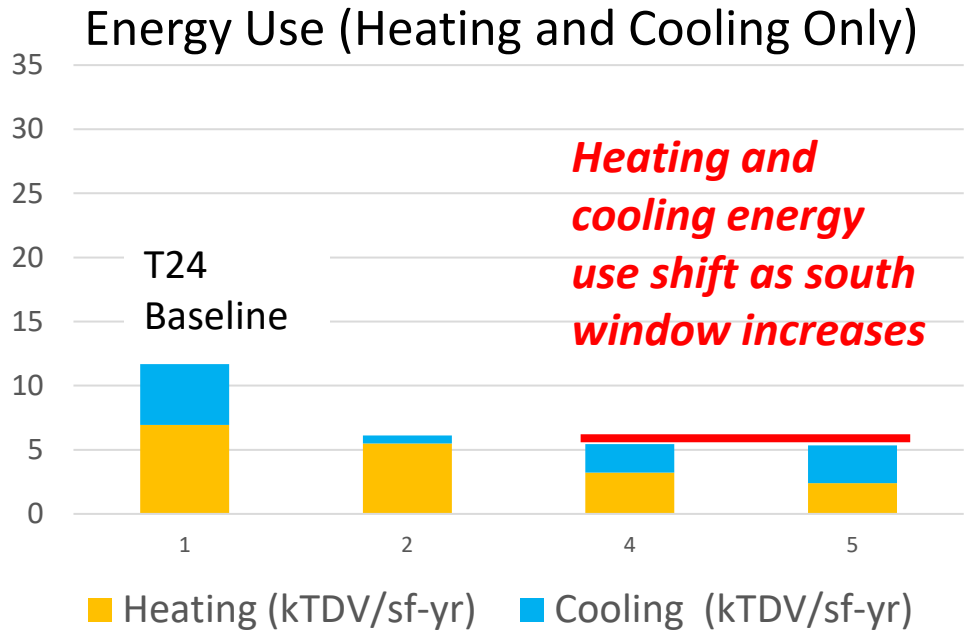
Key Take Away:
"Passive Solar" principles, i.e. orientation, glazing proportions, and insulated thermal mass are still valid energy efficiency strategies and part of good design.

CZ 5:
Similar proportions, but needs solar gains
SHGC 0.35 or higher,
but NOT 0.23

Climate Zone 6

CZ 6 - 2100sf Slab on grade, R-21+R-5 Envelope, SHGC-0.23

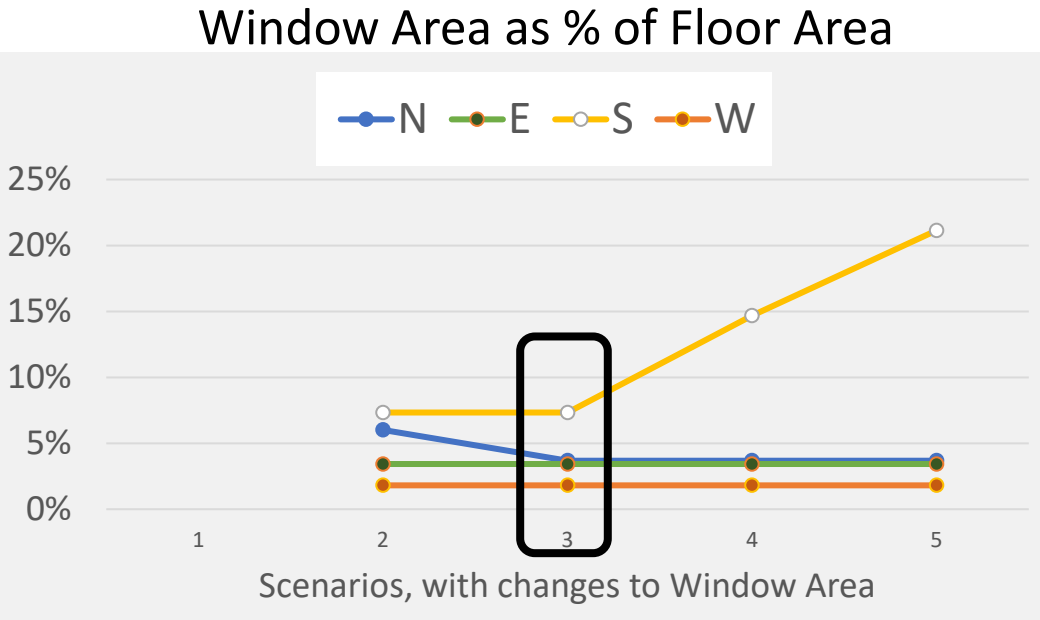


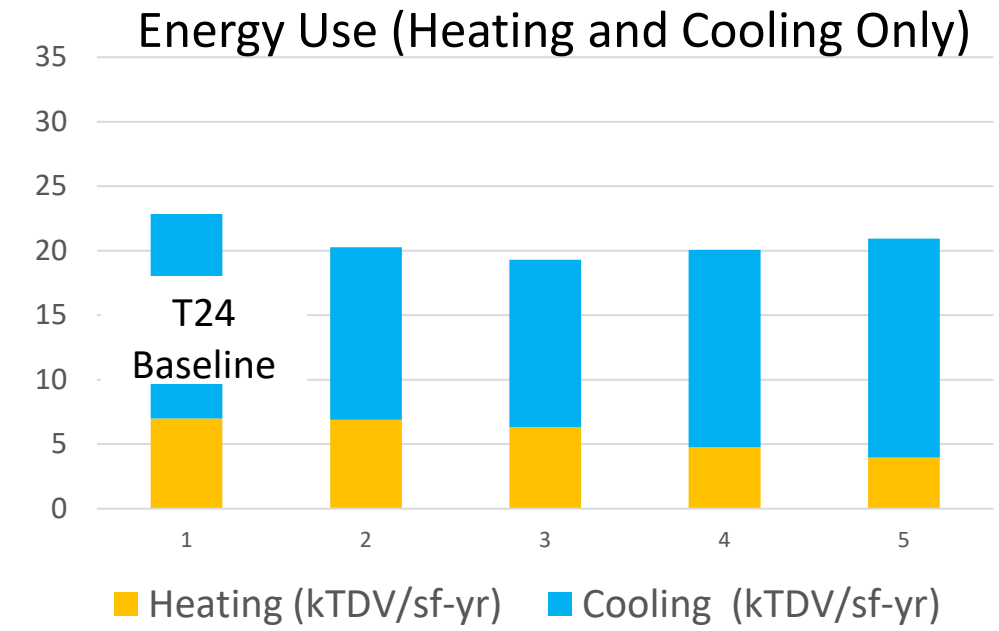


Key Take Away:
Climate Zone 6 is relatively mild with balanced need for heating and cooling when using low SHGC (0.23) windows. Less glass reduces cooling load; high-performance south glass can significantly reduce heating load.

Climate Zone 9

CZ 9 - 2100sf Slab on grade, R-21+R-5 Envelope, SHGC-0.23

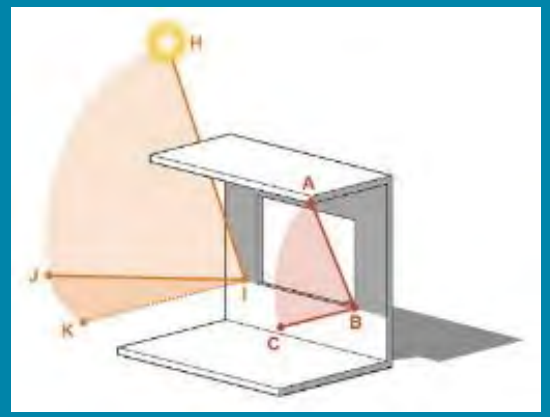




Key Take Away:
Climate Zone 9 has a need for heating, but a significantly greater need for cooling. Strategies that reduce window area and non-winter solar gains are important.

Space conditioning energy use increases as south window increases

Summer and Fall Shade



- South overhangs: Extend 2.5’ to 3’ horizontal per 5 ft window height
- Use side shading for west and east facing windows
- West overhangs/trellis: Extend 10’ to 12’ horizontal for a 6’8” sliding door
- Use seasonal shading for shoulder seasons

Thermal Mass

- Still relevant, stabilizes interior temperatures
- Thermal battery – passive solar, night venting
- Right-size for application, orientation, glazing
- Consider embodied carbon
  - Low-carbon concrete
  - Raised floors with helical piers then add drywall
  - CMU, rammed earth, etc.
- Supports night vent cooling

Insulated, Raised Floor with Tile

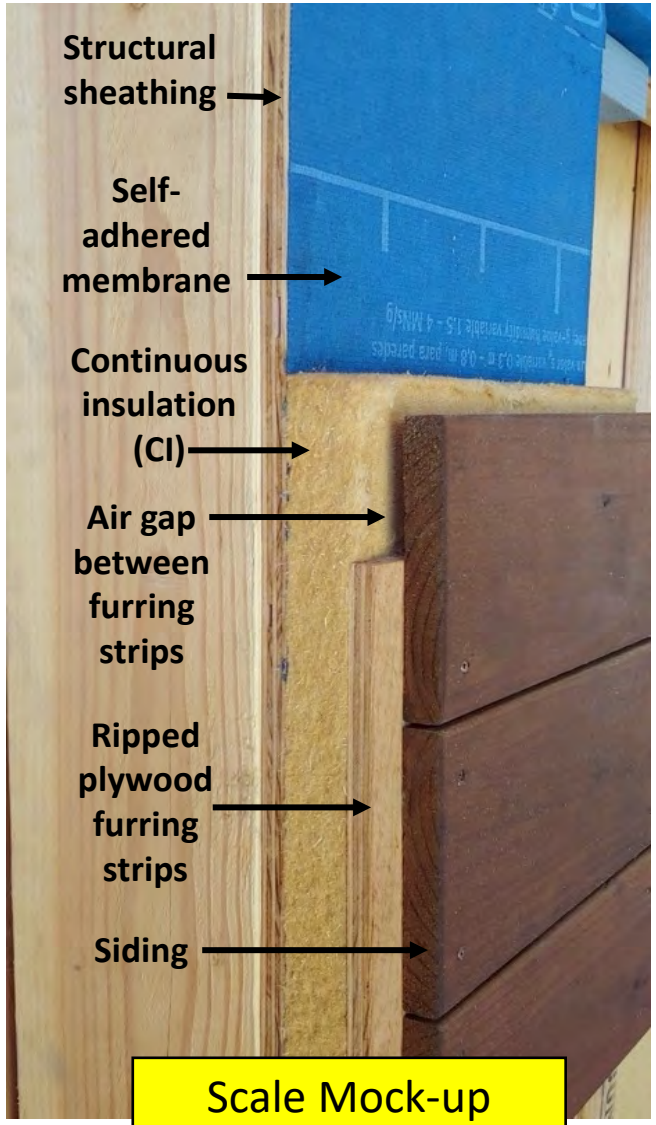
Case Study

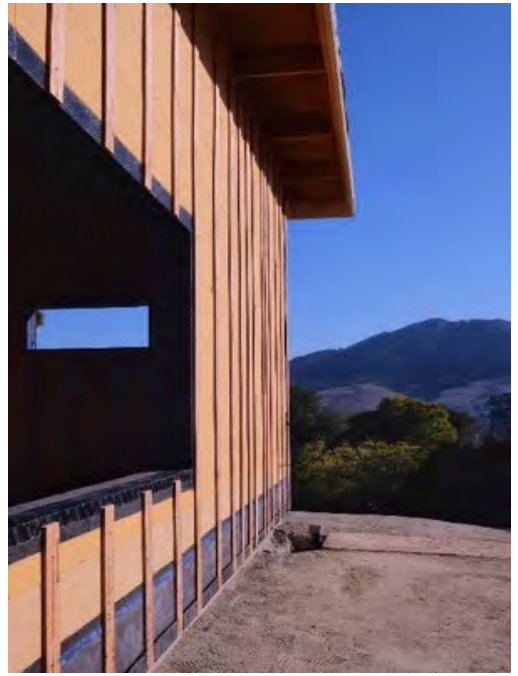
- Orientation within 15 deg of South
- Triple paned windows
- Calculated overhangs for summer shade and winter solar gain
- High-performance envelope
- Insulated slab on grade –exposed concrete floors for thermal mass

Passive House, San Luis Obispo. *Design-Build: Mike Horgan, Cairn Collaborative*

South Elevation

Case Study Con’t



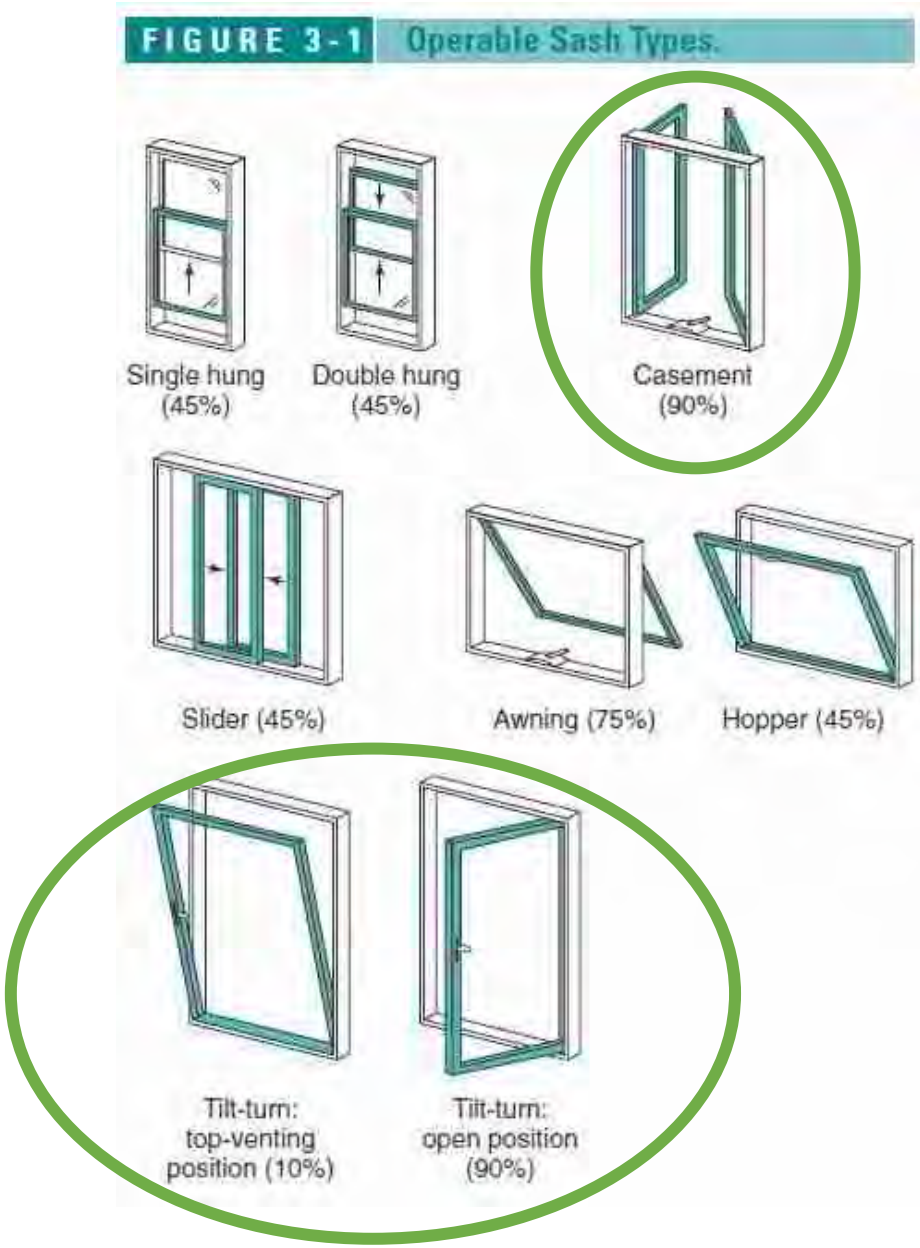


- Operable windows for ‘*free*’ cooling and ventilation
- Insulation: Cavity and continuous exterior
- Air sealing and moisture protection
- Efficient heating and cooling

Ventilation

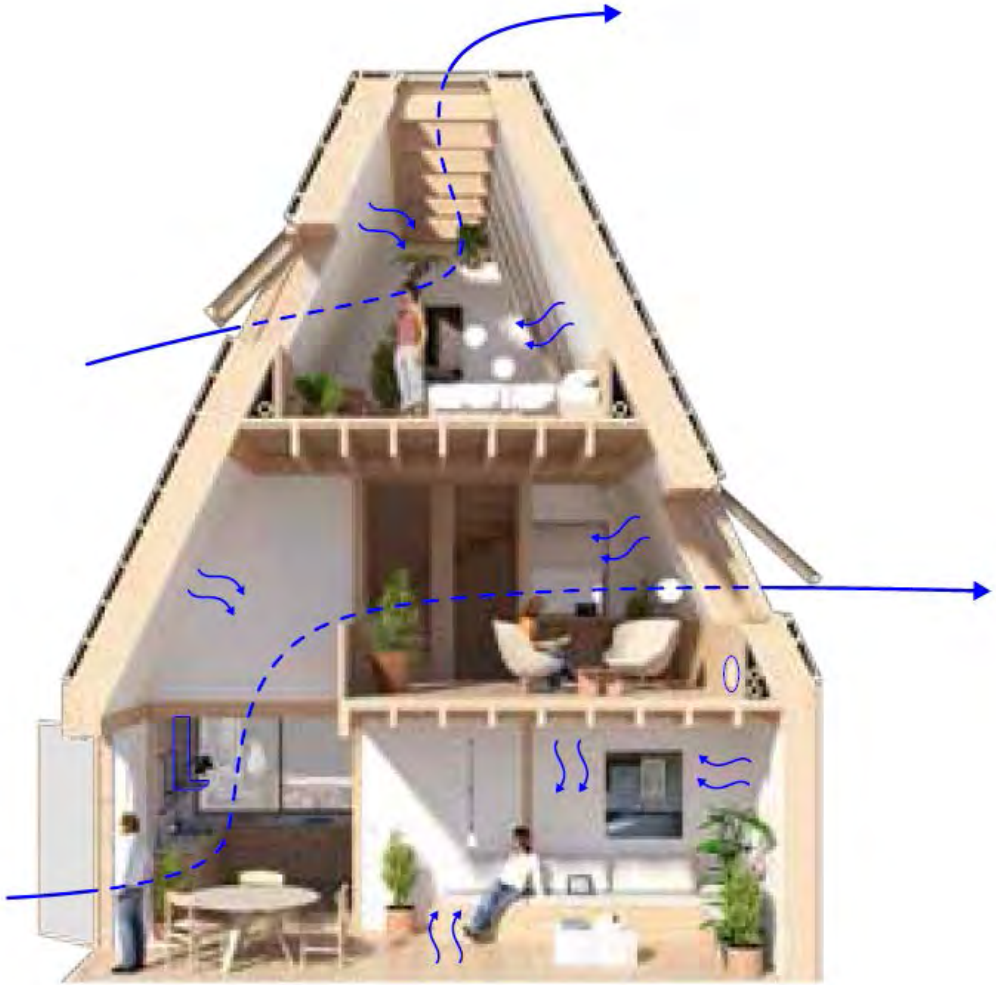
- Operable windows and skylights!
  - Consider Effective Open Area
  - Consider tilt/turn options

  - Look for long-term operability and maintenance
- Automation with CO2 sensors, for Non-res occupancies, and maybe residential



Living Places Copenhagen
Integrating Energy, Daylight & Air Quality

Velux Living Places



Living Places Copenhagen – Energy, Daylight, Air Quality

- Operable windows and skylights
- Open plan for cross ventilation and stack effect
- Automatic controls for CO2, thermal comfort and glare control; close in rain
- Air quality monitoring and reporting
  - NO heating or A/C July and August 2024
  - Thermal Comfort standards met 90% of the time
  - 97% of occupants satisfied with thermal comfort
  - Met EU CO2 Standard (750 ppm max) 89% of the time

Passive Ventilation Guidelines for Central Coast

Cross Ventilation

- Depends on wind speed and distribution of openings
- About 5% of floor area should be net free openings.

A 10’x12’ Room
5% of 120 SF = 6 SF
2’x3’4” casement

Stack Ventilation

- Depends on temperature differential
- 20’ difference between center line of low window to center line of high window is a good starting point

Supplement natural ventilation with fans or ducted systems

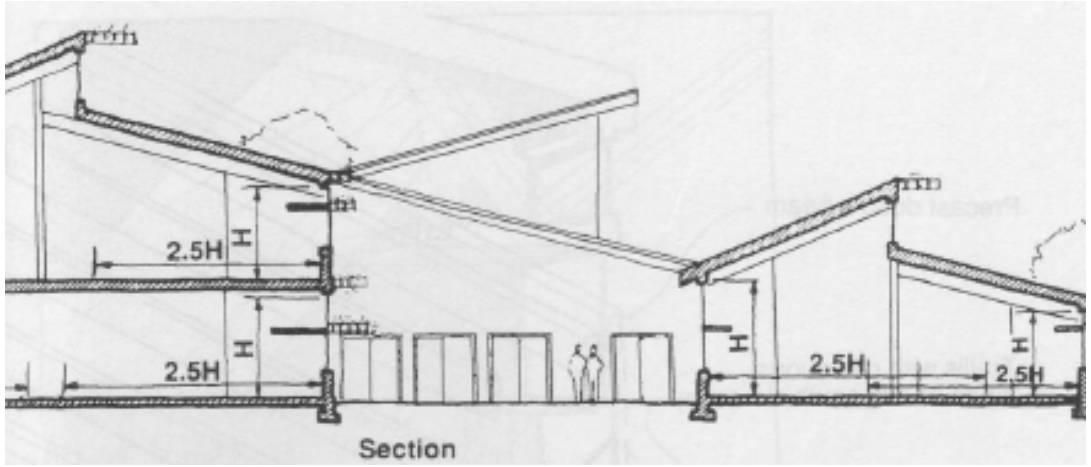
Daylight

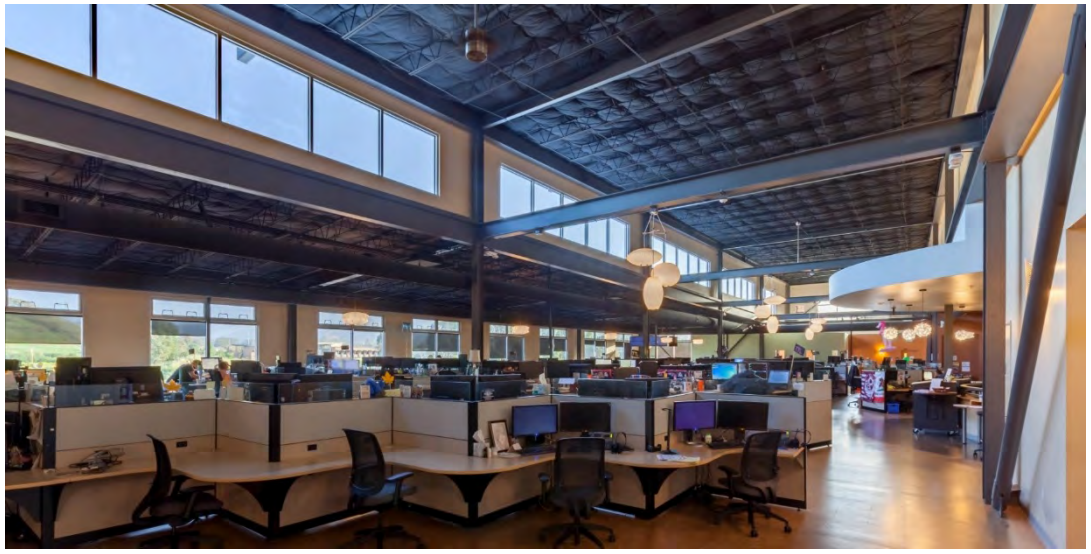
- Daylight for all the *other* reasons
  - May, or may not, help with energy loads
  - Comfort, views, well-being
  - Retail Sales
  - Student Learning
  - Health and Healing

Grand Central Station, Photo credit: Architectural Digest

Window Size and Placement

- Daylight will reach into a room a distance 2 - 2½ times the height of the window
  - Example: A window with a 7’ head height will let light 14-17’ into the room
- Consider use clerestories mid-building





Avoid Glare

- Balanced daylight – at least 2 different directions

- Incorporate adjustable sun control
  - Manual or automatic shades
  - Black-out for user preference
  - Electrochromic Glass
  - Movable exterior awnings

Arrive Hotel, Palm Springs

Clerestory windows provide visual comfort and privacy

Balance daylight with Solar Heat Gain

Visible Light Transmittance (VT)

- Can vary with SHGC
- Higher for more daylight
- 0.40 min. to count for “Views”

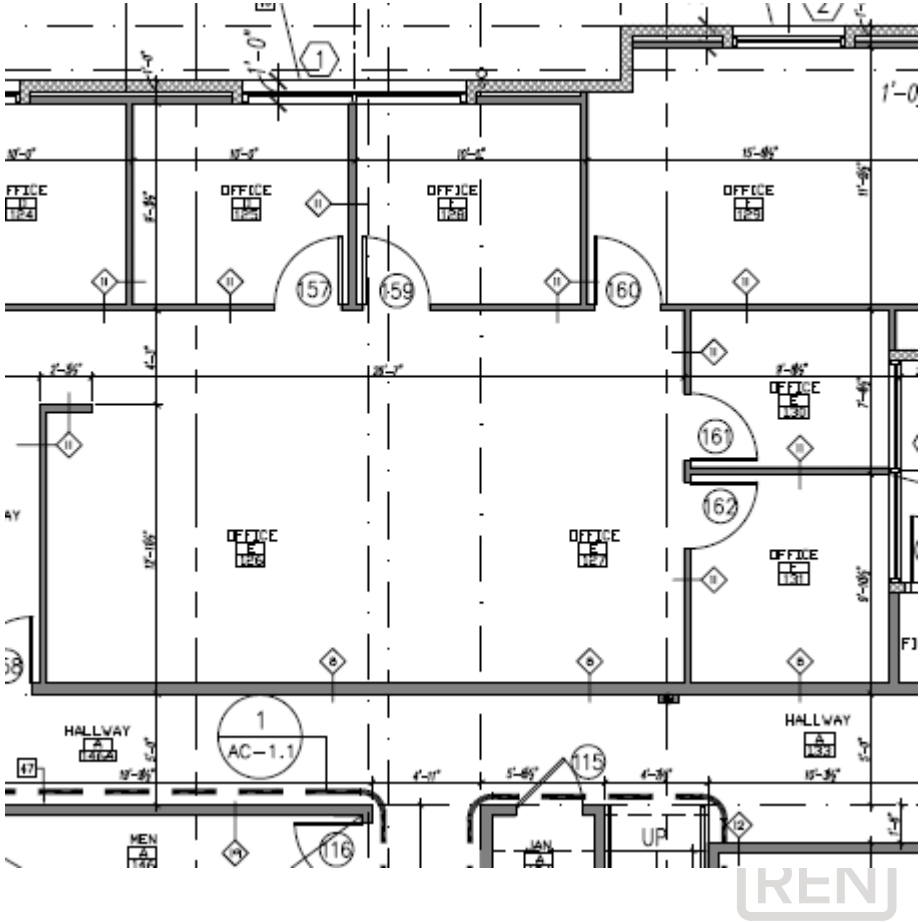
Glass Type	LoE	U-factor	SHGC	VT
Endurance				
3mm/3mm 3/4" OA	452/cl	0.29	0.16	0.38
3mm/3mm 3/4" OA	452/i89	0.25	0.16	0.37
3mm/3mm 3/4" OA	366/cl	0.28	0.22	0.51
3mm/3mm 3/4" OA	366/i89	0.25	0.21	0.5
3mm/3mm 3/4" OA	270/cl	0.29	0.29	0.55
3mm/3mm 3/4" OA	270/i89	0.25	0.29	0.54

Skylights vs. Suntubes

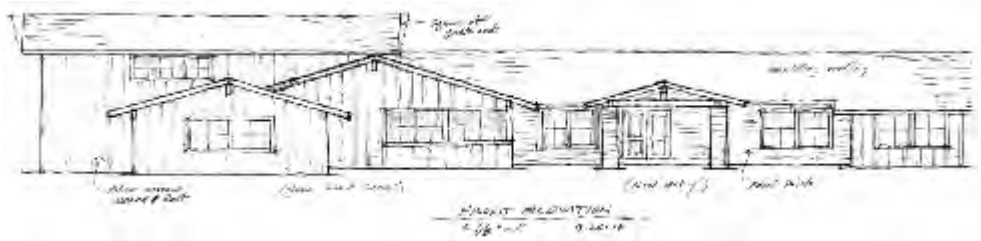
- Suntubes are (almost) thermally invisible
- “Fresnel”-type lens distributes daylight evenly
- But… Doesn’t connect to nature, low drama, not operable, etc.
- Tools to balance daylight (vs. reducing electric lighting)

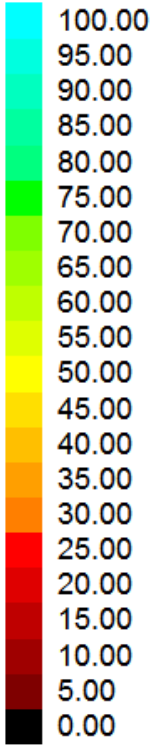
Window-to-Floor Area Alignment

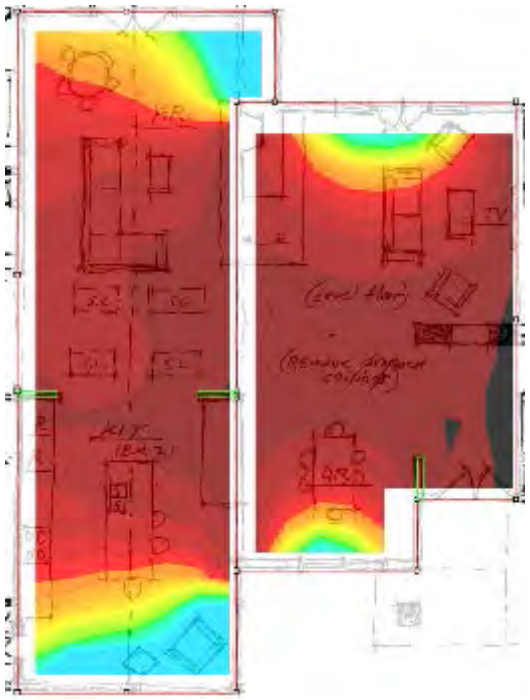
- Pull back individual offices from window walls
- Utilize interior windows for shared light
- Oversized glazing for small office can lead to glare, overheating, lots of roller shades



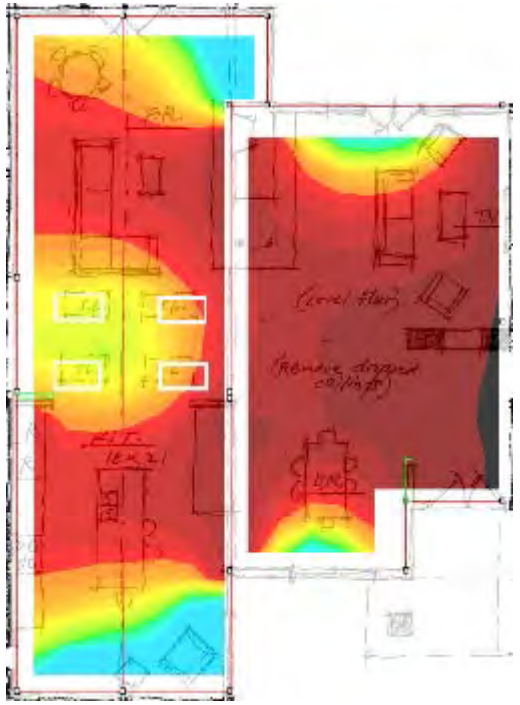
Strategic Toplighting



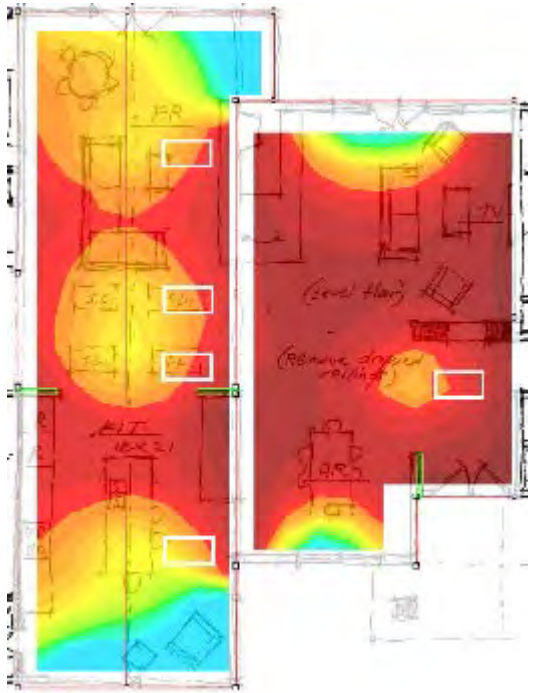




A. No Skylights



B. Central Skylights



C. Distributed Skylights

Complementary Mechanical Systems

- Design for “off”
  - Lighting, HVAC
  - Manual vs. automatic?
- Easy, clear access to whole house ventilation controls
  - Building code requires mechanical ventilation, with an “off” switch
- Air conditioning…? User expectation, community noise vs. open windows

“Fresh Air System: Leave on unless outside air is very poor”
… or when using natural ventilation.
Credit: Home Ventilating Institute

What’s Next

Morerava Cottages, Chile, AATA Arquitectos

Passive Solar Design – Alive and Well!

Emerging Concerns

- Fire risks, smoke, indoor air quality
- Floods, droughts
- Power outages
- Load shifting, strain on the grid

Emerging Opportunities

- Technology advances in energy, energy storage and microgrids
- Better design, detailing, materials
- Global awareness & leadership
- Regenerative Design approach

Forest Building, Milan; Boeri Studio

Regenerative Design

Code Compliant
- Less Bad

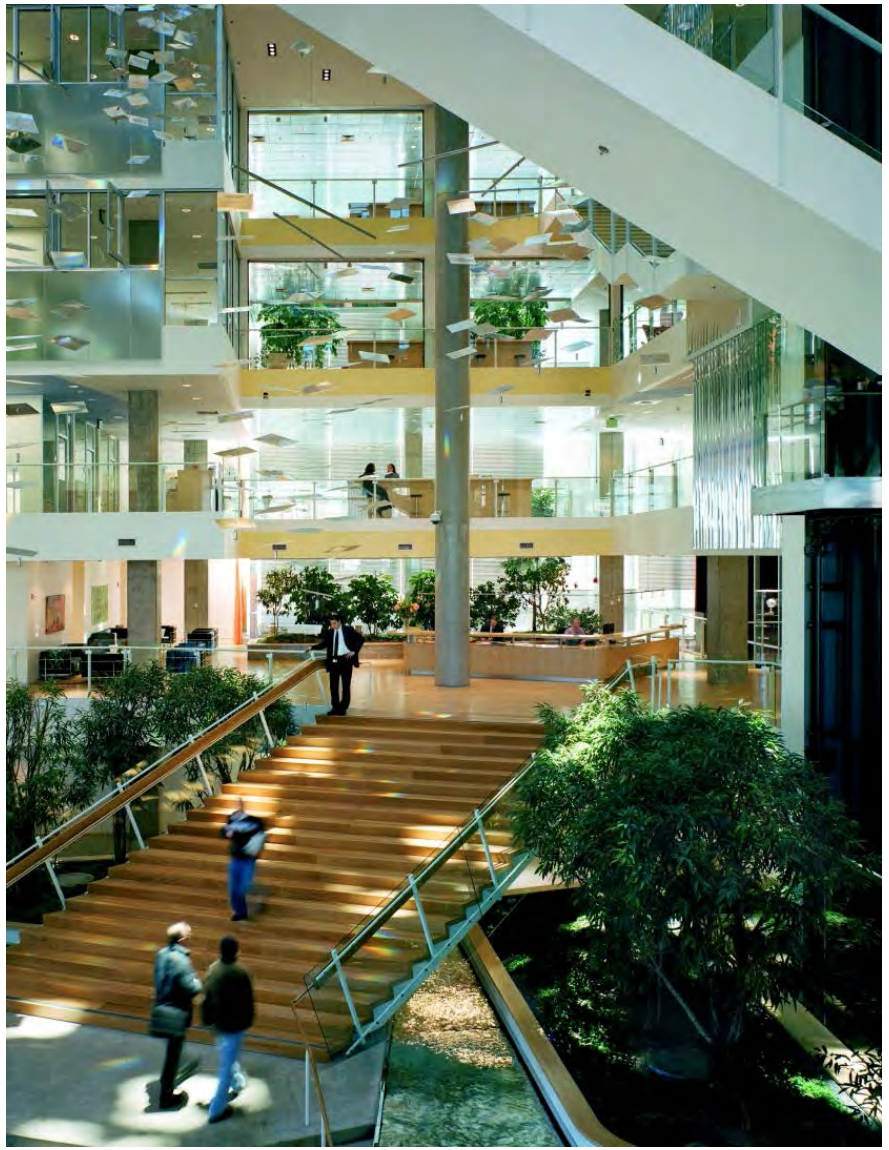
Sustainable
- Neutral

Regenerative
- Healing

Germantown Friends School, SMP Architects

Biophilic Design

- Connects occupants with nature
  - Plants, daylight, views, natural materials
  - Spatial arrangements to mimic natural environments
- Passive Design strategies can dovetail with Biophilia
  - Daylight w/ circadian rhythms
  - Natural ventilation, gentle air movement
  - Plants and water elements

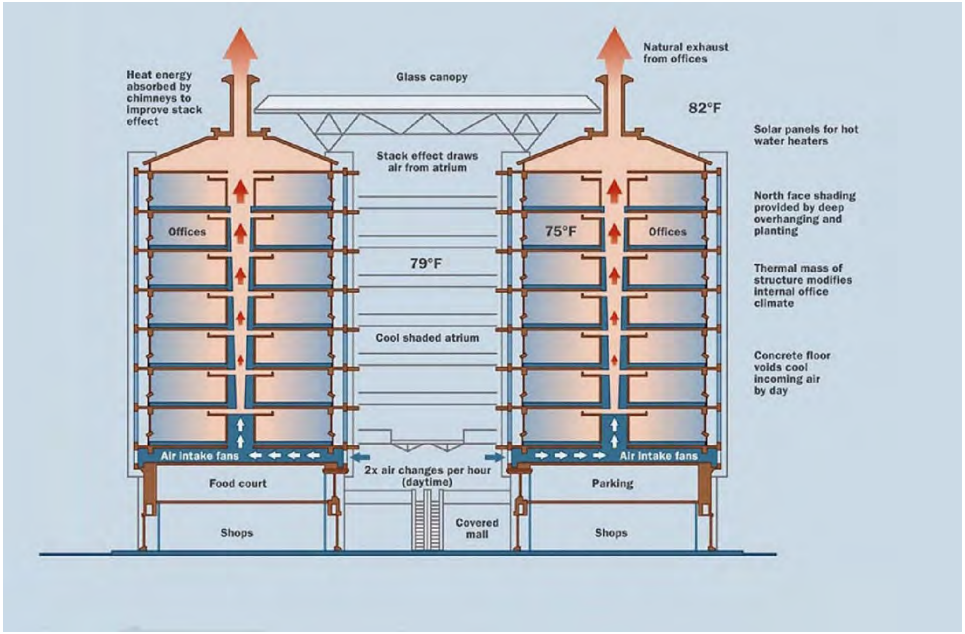


Source: Stephen Kellert, *Nature By Design*

Biomimicry

Local termite mound has a complex system of tunnels and stack-effect ventilation

- Modeled on Natural Systems
- Eastgate Centre, Zimbabwe
  - Air shafts for stack effect
  - Crenulated thermal mass



System Design Credit: Arup

Wrap Up & Discussion

1. Site-responsive Design is timeless
2. Passive Solar Principles still effective, with key updates
3. Continue integrating strategies to reduce energy, improve health and comfort and promote resilience.

Thank you!

Thanks for Attending!

Continuing Education Units Available

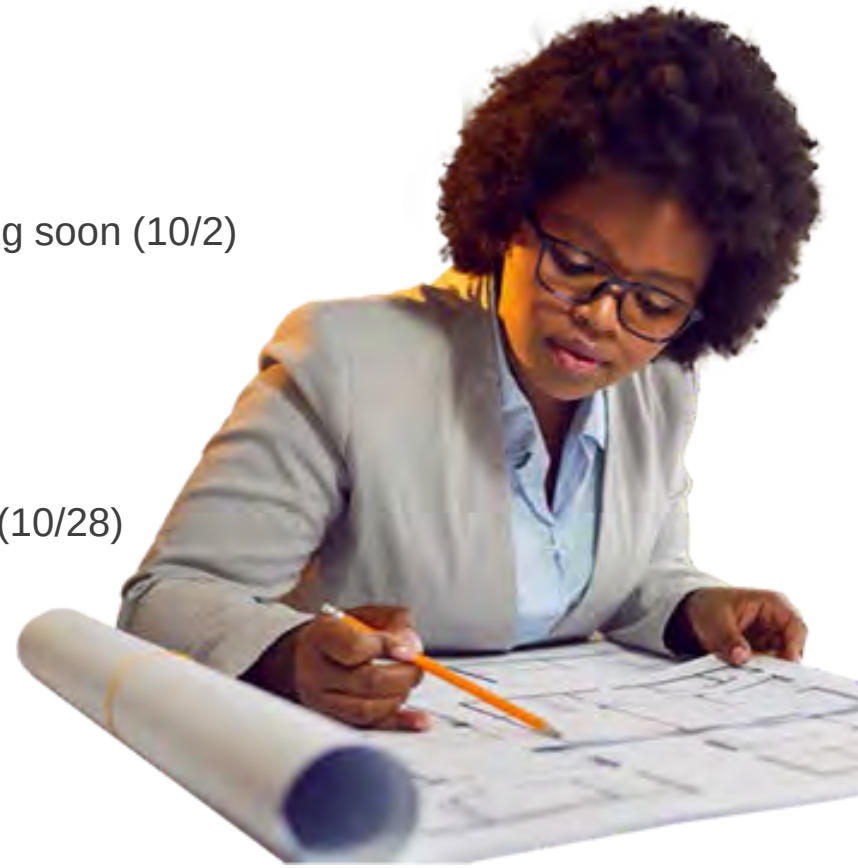
- Contact chloe.swick@venturacounty.gov for AIA LUs

Coming to Your Inbox Soon!

- Slides & Recording

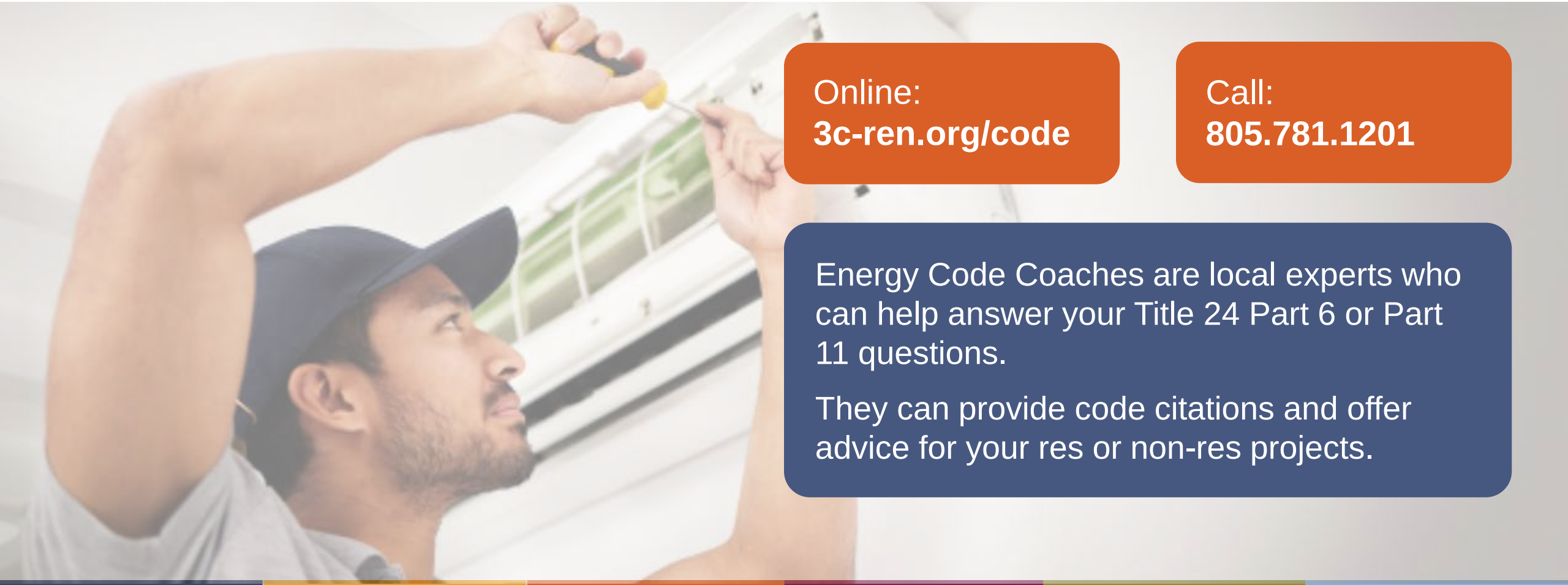
Upcoming Courses:

- **Last Call!** *Certified Passive House Designer/Consultant Fall Cohort* signups closing soon (10/2)
- Energy Code Compliance: Using HERS/ECC Measures (Part 1) (10/8)
- All Electric Retrofit with Electric Panel Constraints (10/23)
- Health and Resilience of Clean Energy Homes (10/28)
- Happy Hour in Santa Barbara Renewable Energy, Energy Storage and Resilience (10/28)



Questions about Title 24?

3C-REN offers a *free* Code Coach Service



Online:
3c-ren.org/code

Call:
805.781.1201

Energy Code Coaches are local experts who can help answer your Title 24 Part 6 or Part 11 questions.

They can provide code citations and offer advice for your res or non-res projects.

Thank you!

More info: [3c-ren.org](3c-ren.org)

Questions: **info@3c-ren.org**

Email updates: **3c-ren.org/newsletter**

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