EEBA High Performance Home Summit

Salt Lake City, UT, Oct. 10-12, 2023

Building for the New Normal: Disaster-Resistant Construction

Theresa Gilbride and Christian Kaltreider,
Pacific Northwest National Laboratory

EEBA
Energy & Environmental Building Alliance

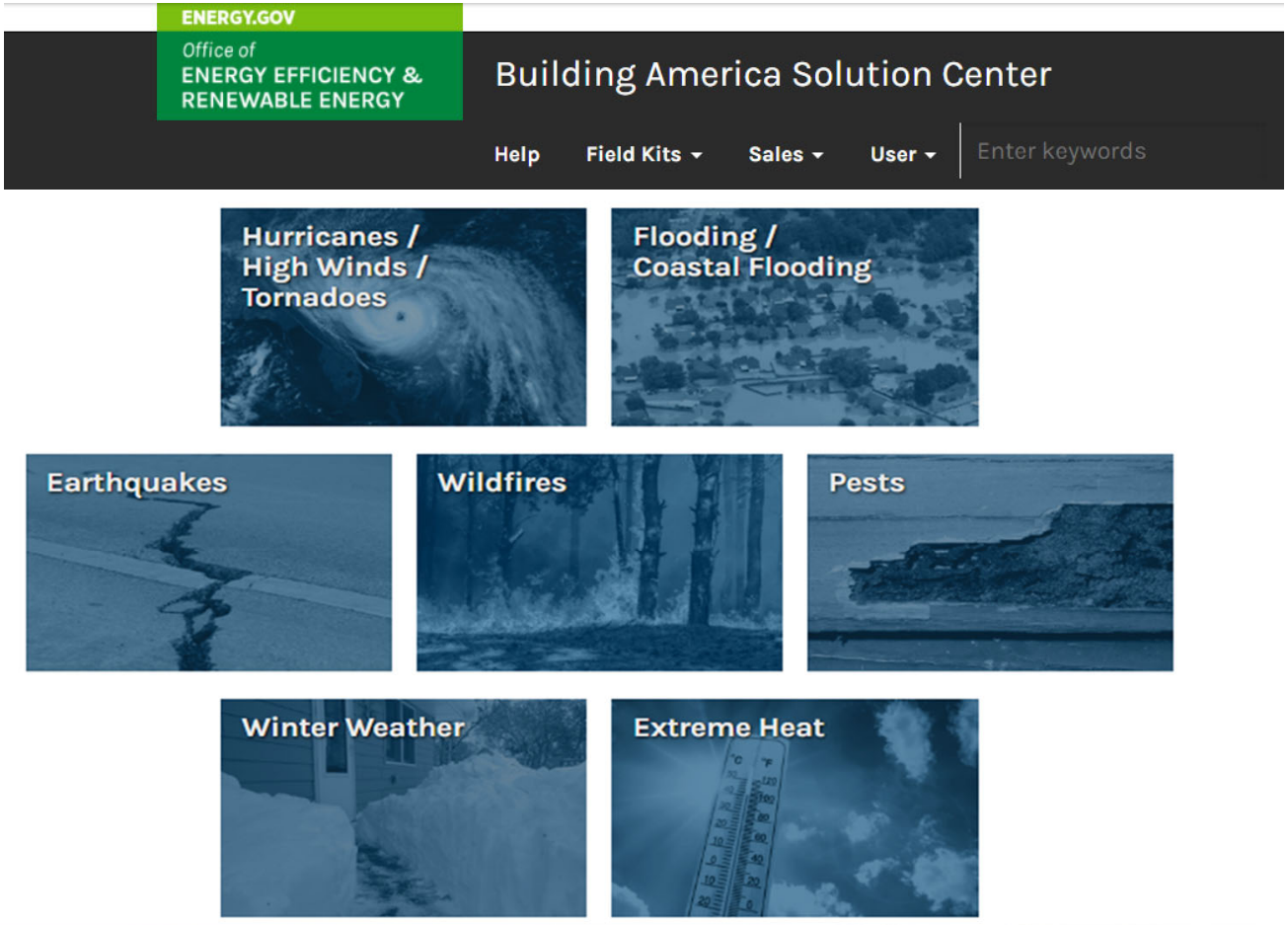
Presentation Overview

- Discuss the value of being pro-active rather than re-active to natural disasters.
- Identify top tips for retrofitting homes to be more resistant to hurricanes, floods, earthquakes, wildfires, heat waves, and severe winter weather.
- Find out how many of these steps can make homes more energy efficient, durable, and comfortable too.
- Learn how to find disaster-resistant, energy-efficient solutions in DOE's Building America Solution Center's Disaster Resistance Tool.

Terri Gilbride,
Building Scientist

Christian Kaltreider,
Building Scientist

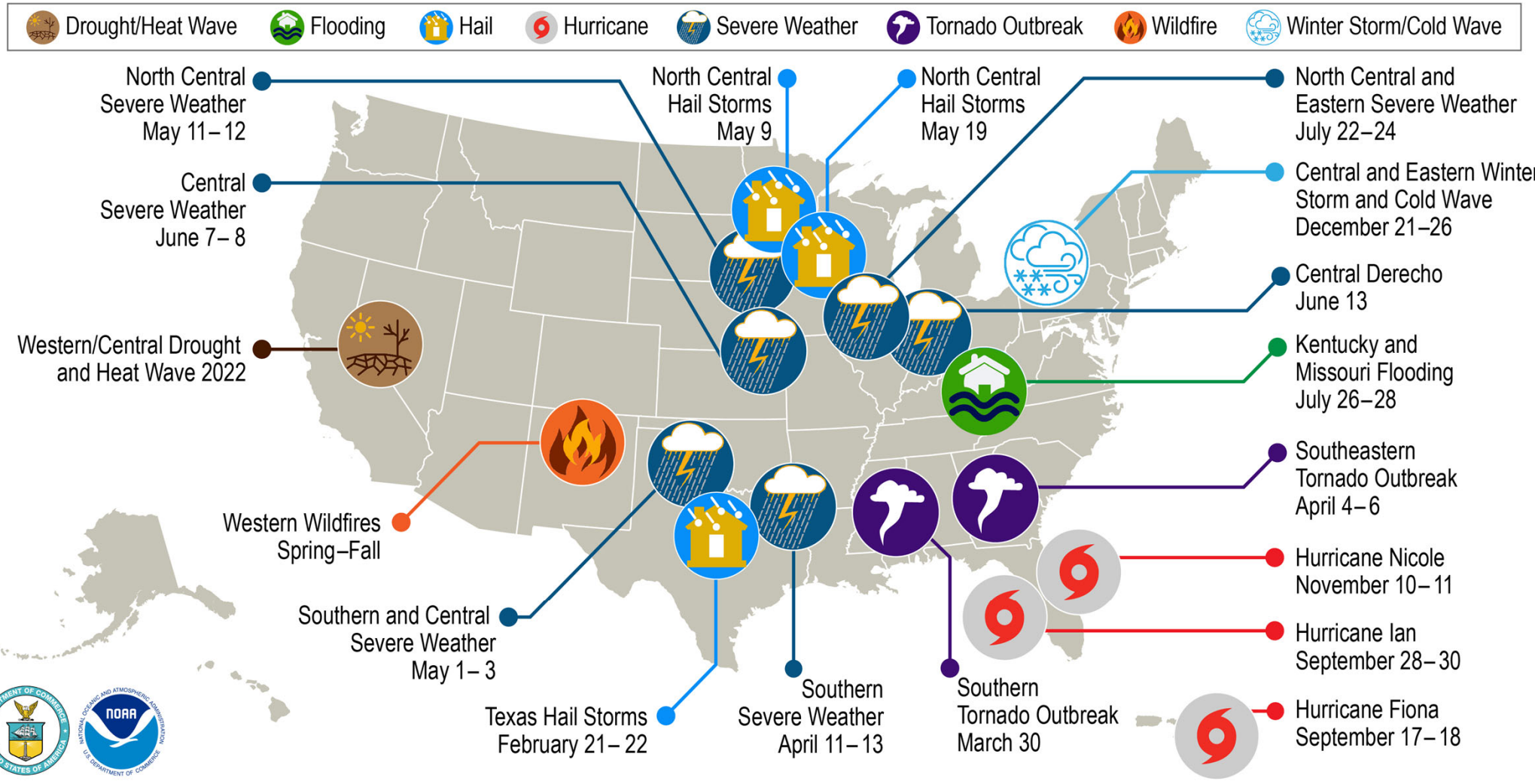
Building America Solution Center
www.pnnl.basc.gov



We'll focus on a few today:

- Hurricanes
- Floods
- Earthquakes
- Wildfires
- Winter Weather
- Extreme Heat

U.S. 2022 Billion-Dollar Weather and Climate Disasters



*This map denotes the approximate location for each of the **18 separate billion-dollar weather and climate disasters that impacted the United States in 2022.***

Source: NOAA National Centers for Environmental Information

Natural Disasters are costly

In 2021, natural disasters cost Americans $145 billion according to NOAA. These costs include:

- Biggest losses - Physical damage to residential, commercial, and government or municipal buildings and material assets within buildings
- All other losses (infrastructure, ag, business interruption, vehicles, restoration)
- Does not count – LOSS of LIFE

NOAA concludes:

- "Building codes are often insufficient in reducing damage from extreme events."
- "Where we build and **how** we build determines our resilience to the increasing risk of disaster events."

Source: NOAA National Centers for Environmental Information

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How to be a survivor

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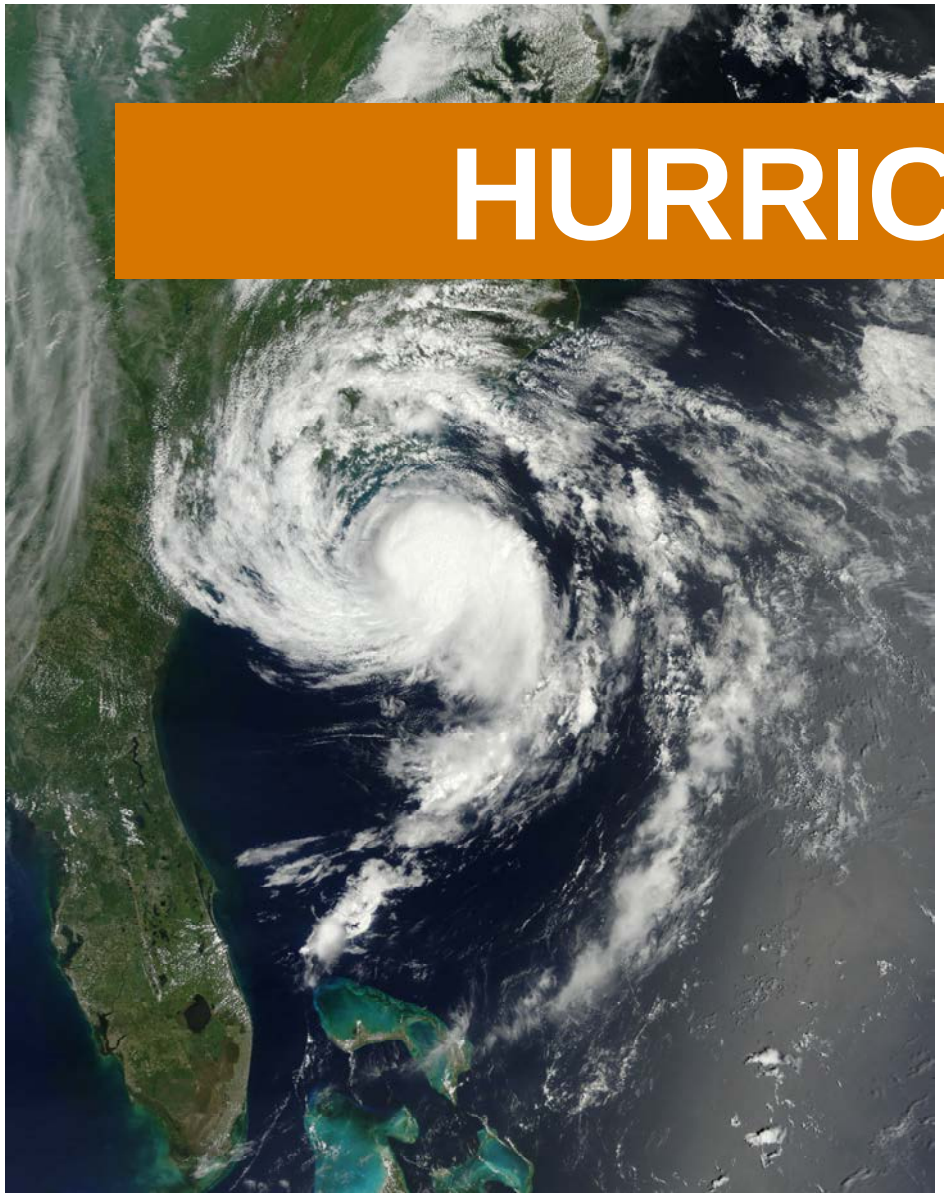
HURRICANES



Source: NOAA

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The Tale of Two Communities

IBHS Fortified Duplexes survive Hurricane Ida

These homes are part of Les Maisons de Bayou Lafourche, a 35-unit storm-resilient affordable housing community near New Orleans.

- Elevated concrete foundations
- Impact-rated doors and windows
- Standing seam metal roofs, no gable overhangs.
- Engineered framing with metal hurricane anchors and bolts
- Continuous load path to
  - Tie the structure of the house together
  - Direct extreme wind forces to the ground.

IBHS Fortified Roof Requirements

Hurricane-Proofing New Homes

Roof Deck	≥ 7/16” OSB or plywood. 8d ring shank nails, every 6: on edge, every 12” in field. Hail: Impact rated for hail.
Seal the Deck	3 Options: 1: Cover whole deck with self-adhering polymer-modified bitumen membrane. 2: Tape all seams with bitumen tape or self-adhering flashing. Cover with underlayment cap nailed every 6”/12”. 3: Install two layers of underlayment in shingle fashion.
Drip Edge	Install at eaves and rakes, over the underlayment. Fasten to deck, seal upper edge with flashing cement.
Shingles	Install ASTM D3161 Class F or ASTM 7158 Class G/H rated shingles. In hail-prone areas, use UL 2218 Class 4 impact-rated shingles. 4 nails per shingle.
Gables	Cover gable end vents with permanent shutters or removable 7/16” plywood and permanent mounting hardware. Construct gable end wall with 7/16” plywood or OSB sheathing. Connect gables > 12” to interior framing.
Roof Vents	Must meet Florida Building Code TAS 100 (A).
Porches & Carports	Use metal connectors to connect roof framing to beam, beam to - columns, columns to structure.
Garages	Is impact rated or protected with: • Horizontal and vertical bracing. • Track brackets anchored to the wall. • Steel door panels. • Stronger rollers, hardware, and hinges.
Exterior Doors, Windows, Skylights	Exterior doors are impact and pressure rated. Or, fitted with shutters or protective coverings. Windows and glass doors are pressure and impact rated. Hail: Skylights and PV panels are hail impact rated.
Walls	Have 7/16” plywood or OSB sheathing
Chimney	Connect to roof framing.
Continuous Load Path	Connect roof to walls and walls to foundation with metal connectors.

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Roof + Re-Roofing

More on Roofs

For a vented attic,

- Use hurricane-rated ridge and soffit vents, no gable vents.
- Use fiber cement, not vinyl, soffit covers. Fasten with screws or nails.

Or, Install an Unvented Attic

- Stops wind-driven rain entry (and pests)
- Reduces risk of roof blowing off.
- Conditioned space for HVAC and storage.
- Closed-cell spray foam insulates, air seals, and glues down the roof.

Hurricane Construction – Shore up the Weak Spots

Roof shingles – use starter strips and 6 nails per

Brace gable-ends or use hip roofs

Install metal connectors for continuous load path

- Reinforce or avoid overhangs
- Unvented attics, solid soffits
- Termite/mold-resistant borate lumber and concrete block

Strengthen or avoid attachments (fences, pergolas)

Install impact-rated doors and windows

Garage doors – pressure rated, reinforced hardware

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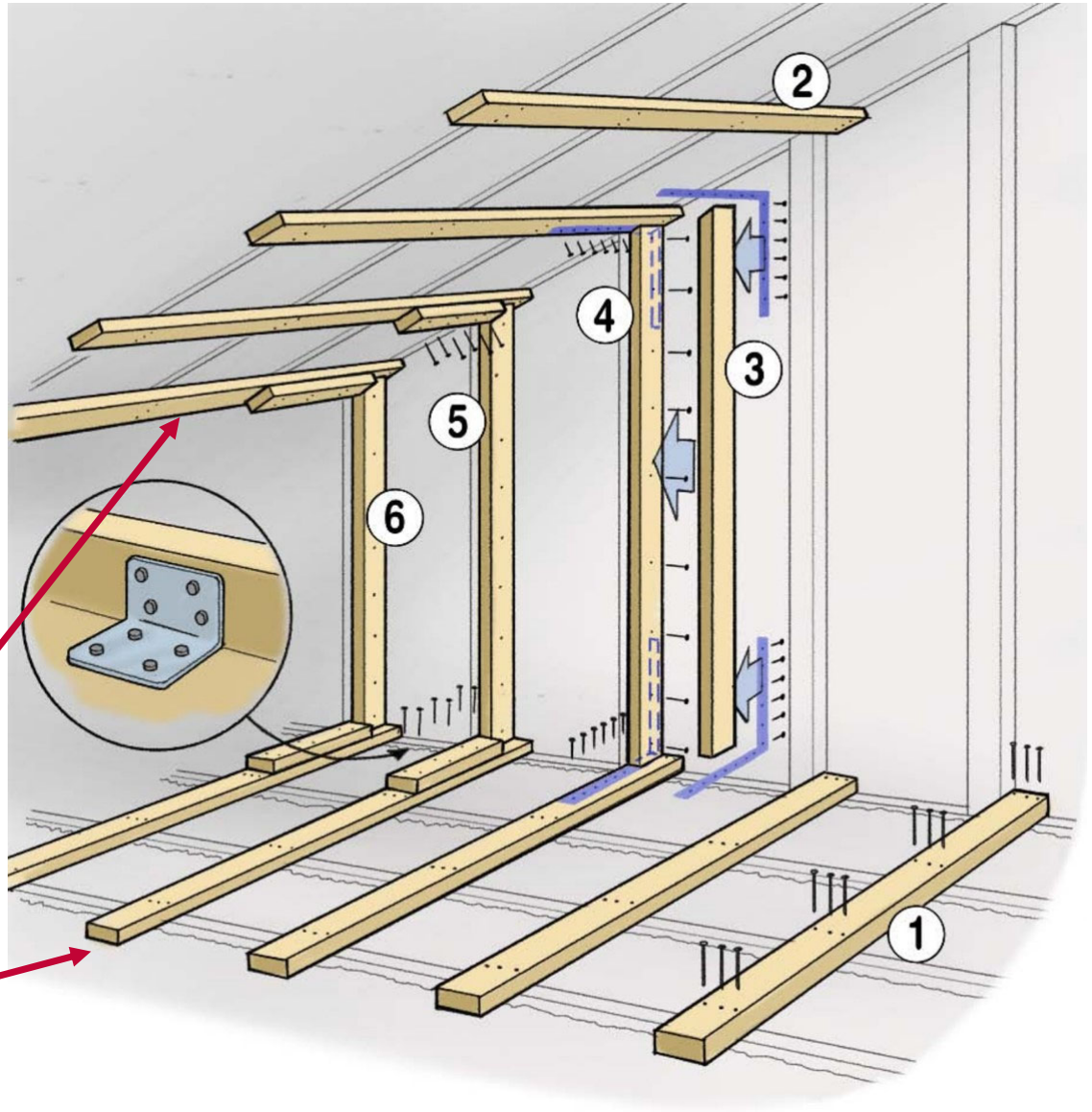
Resisting Hurricanes -
New and Retrofit

Prevent this

with this



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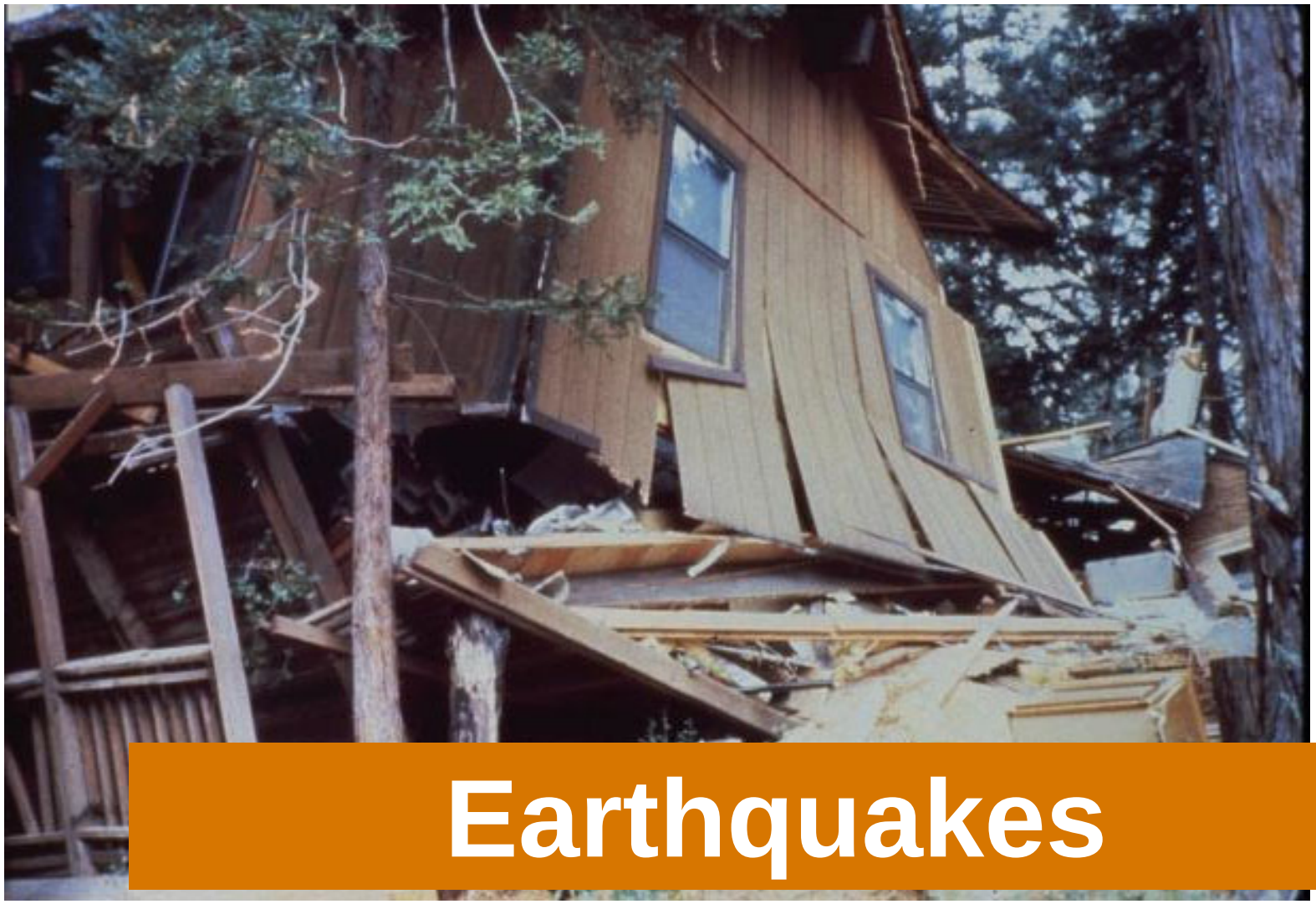


Earthquakes

Source: NOAA

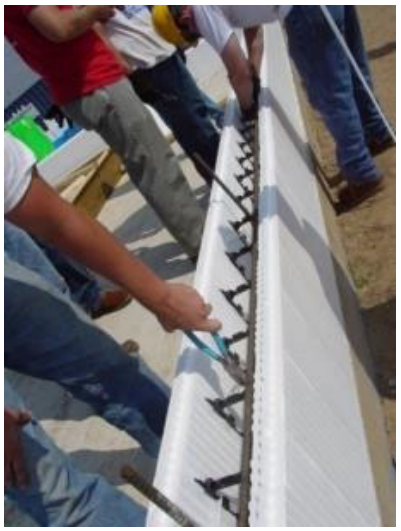
What does it take to resist a quake?

Only 6 homes remained standing near the epicenter of the "Great Hanshine" earthquake in Kobe, Japan, in 1995. All were SIP homes.

Earthquake Resistant SIPS and ICFs

Structural Insulated Panels

- High racking resistance from fully glued sheathing
- SIPs are suitable as shear walls in high-seismic zones D, E, and F
- Truly continuous insulation (no studs)
- Airtight seams



Insulated Concrete Forms

- Steel-reinforced concrete core
- High R, continuous insulation
- Mold, moisture, and bug resistant

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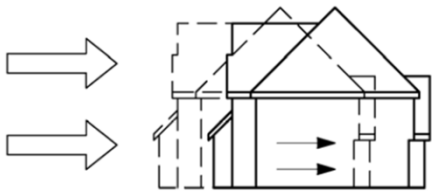
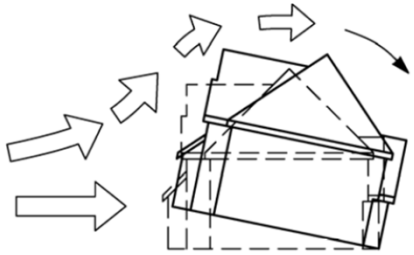
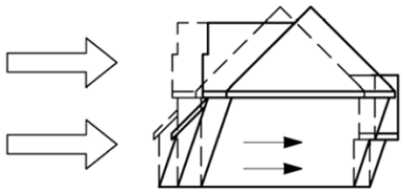
Connect Roof to Ground



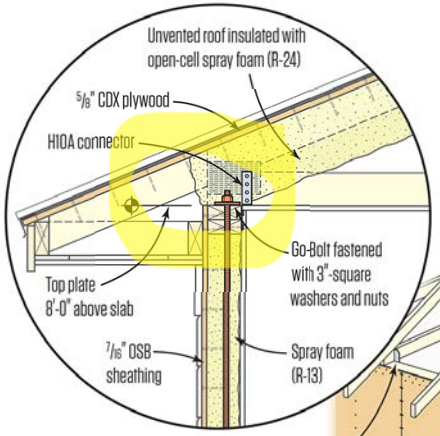
Sliding



Overturning



Racking

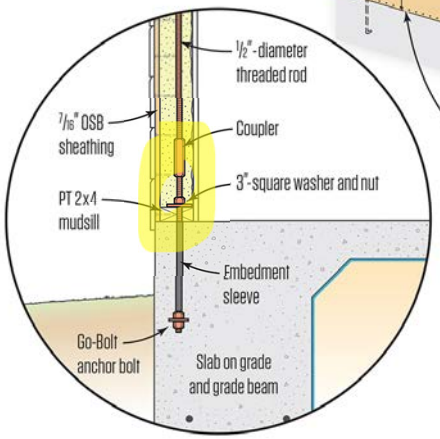


Go-Bolt threaded rod connectors run from the foundation to above the top plate. Spaced within 8" of all corners and window and door openings, and 6'-0" o.c. within the rest of the wall.

Hip roofs sheathed with 5/8" CDX plywood nailed at 4" o.c. with 8d ring-shank nails (sheathing not shown for clarity)

Roof-to-wall connection. The hip roof trusses are secured to wall plates using Simpson H10A connectors.

Anchoring the sill plate. In addition to the Go-Bolt connectors, 5/8" anchor bolts were installed through 3"-square plate washers, 32" to 48" o.c.



Walls sheathed with full-length OSB panels, which provides continuous sheathing from base to top of wall. The 7/16"-thick sheathing was nailed off with a double row of 8d nails 2 1/2" o.c. (staggered) at top plate and a single row of 8d nails 2 1/2" o.c. at bottom plate (mudsill). All seams were nailed off at 4" o.c. (as well as the sheathing's field nailing).

Hip roof overhang secured with Simpson MSTA24 strap ties at post-to-beam and beam-pocket locations and Simpson ABU66Z stand-off base anchors. Roof trusses at overhang are secured to wall plates and beams with Simpson H10A connectors. Hip and jack rafters not shown for clarity.

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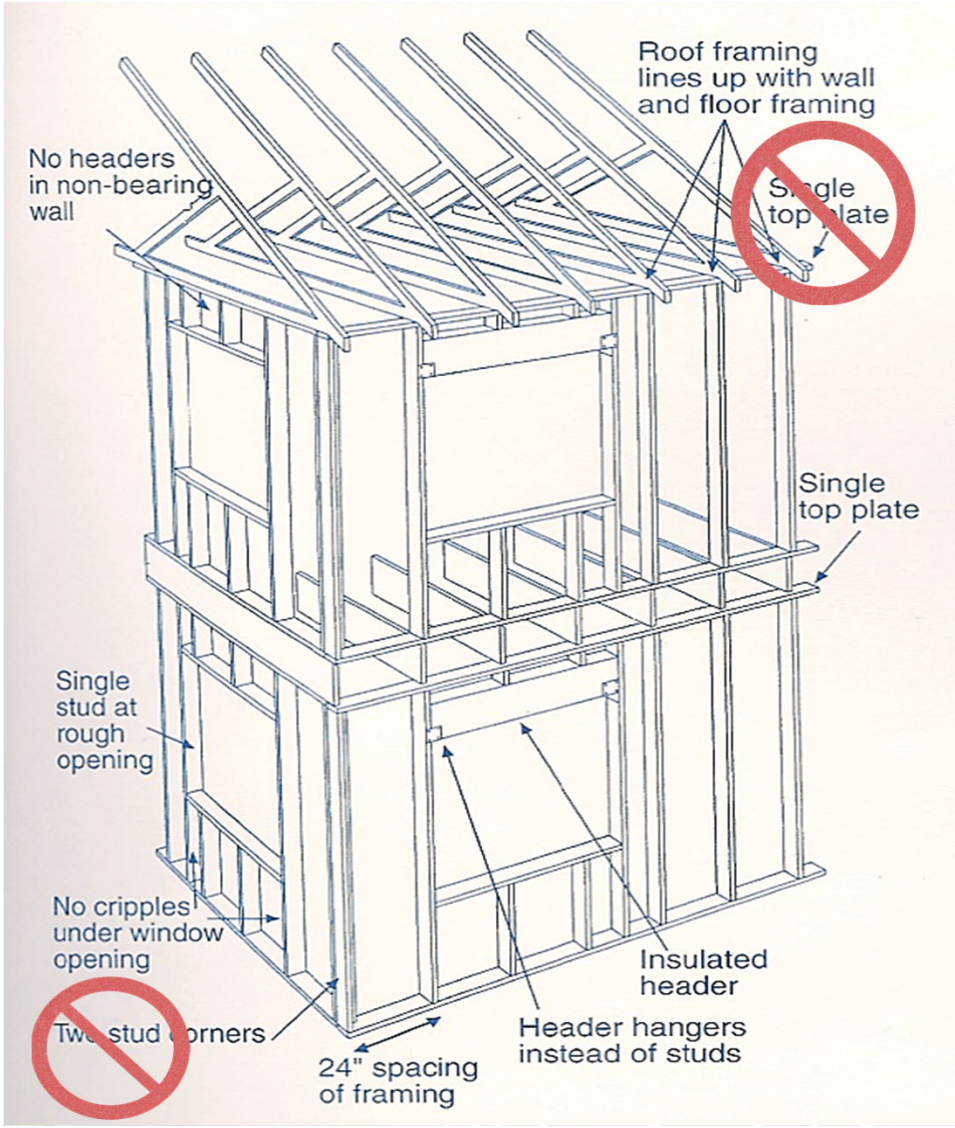
Continuous Load Path

Advanced Framing on
2-foot Grid makes this easier



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FLOODS

Source: NOAA

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Building for the Flood

Pre Katrina

Post Katrina

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Building America Prototype
Post-Katrina *Green Dream* Homes 1 & 2

(Flood-hardy, strong, durable, energy-efficient, healthy, affordable)

- **Flood-hardy** building assemblies
- **Termite-resistant** borate-treated lumber, plywood
- **Rain, moisture, air** and **thermal controls**
- **HVAC** for low energy and healthy home

bsc Building Science Corporation

LaHouse Home and Landscape Resource Center

Catholic Charities Archdiocese of New Orleans

Building America U.S. DEPARTMENT OF ENERGY

“Flood-Hardy” Washable, Dryable Walls and Floors

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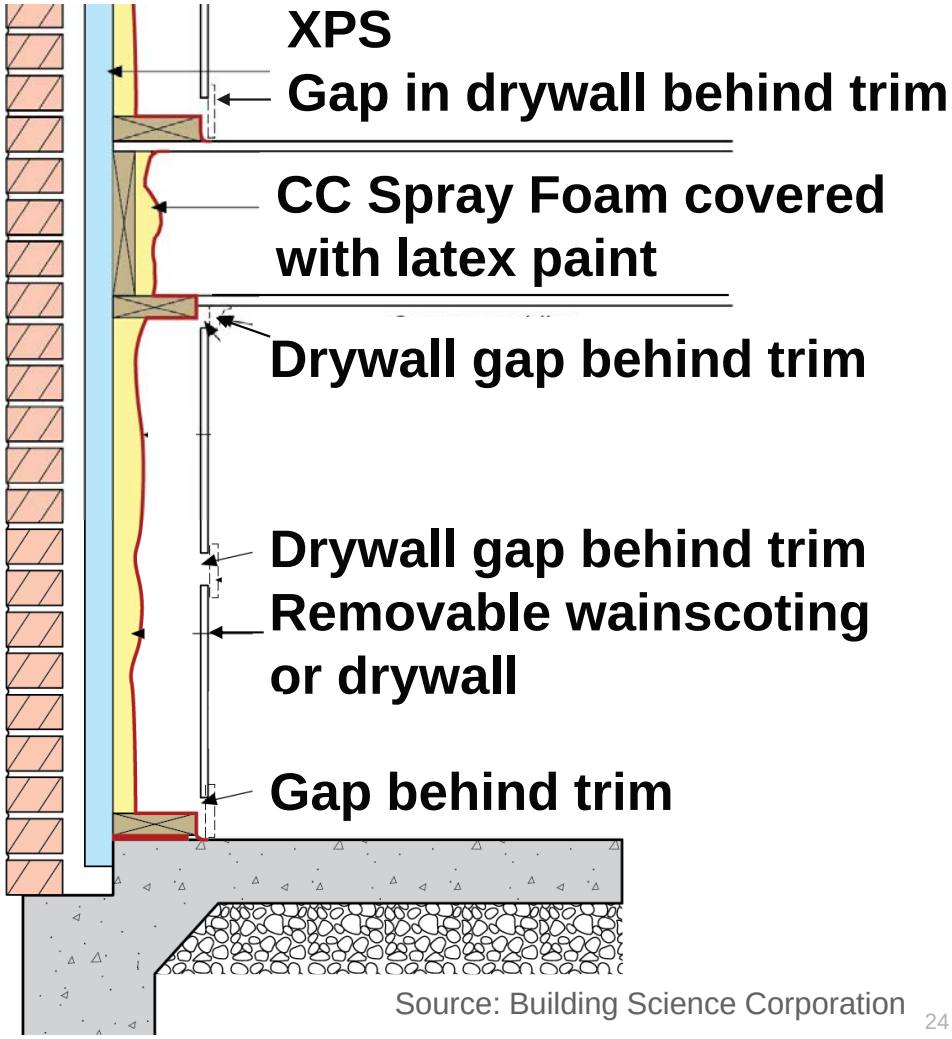
- Use moisture-resistant materials.
- For walls: Pressure-treated, borate-treated lumber, paperless drywall, plywood, fiber-cement sheathing, PVC trim.
- For flooring: use sealed concrete; ceramic or porcelain tile or brick flooring with water-proof mortar; or floating vinyl.
- Insulate walls with rigid foam or closed-cell spray foam.
- Leave gaps behind trim at top, chair rail, and baseboard or vinyl wainscoting.
- After flood, remove trim, rinse, sanitize, and dry cavities. Replace drywall where needed.



Source: Building Science Corporation

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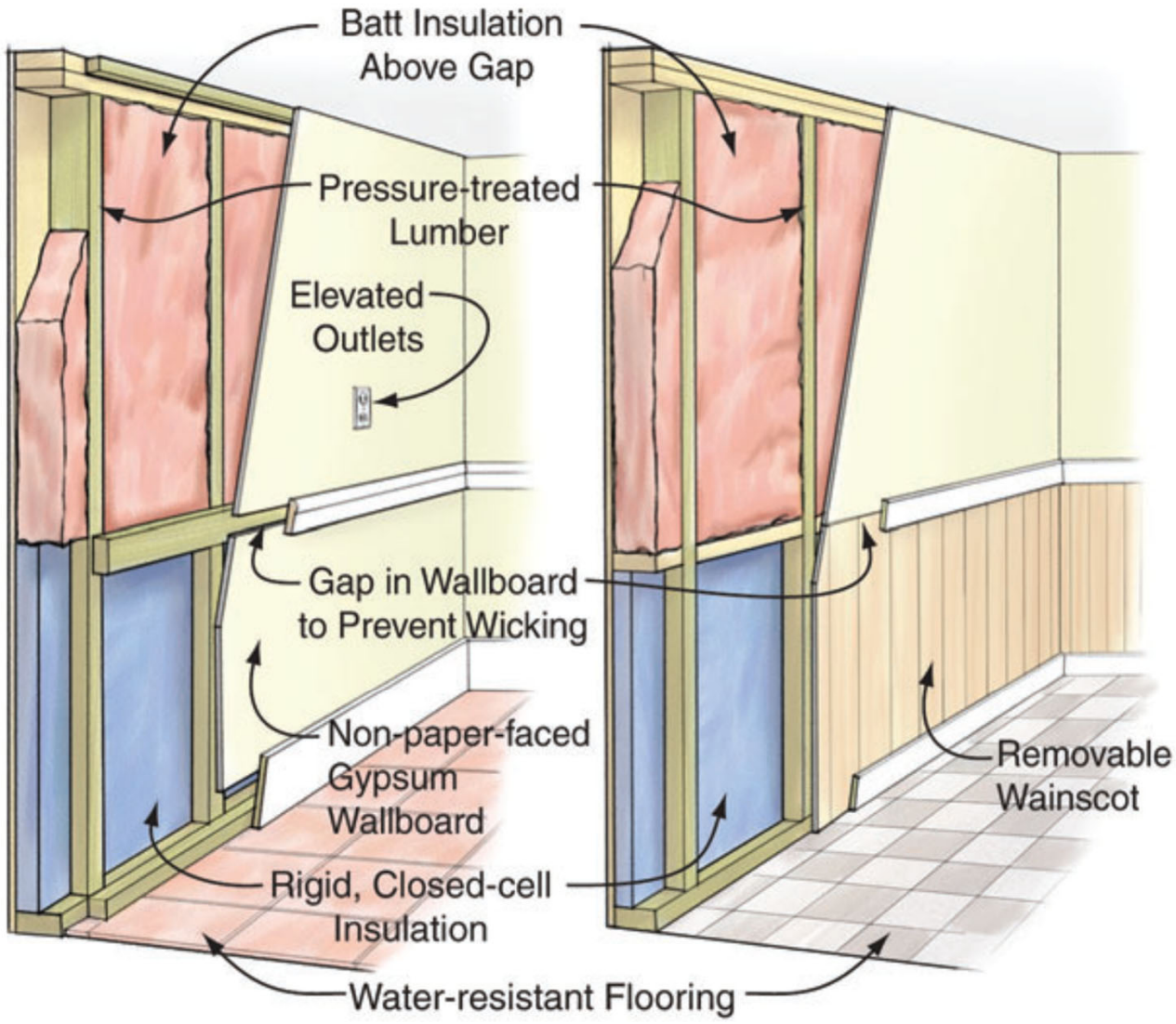
"Flood-Hardy" Walls



Putting it all together

DOE ZER home in Construction

Finished DOE ZER home

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Wildfires

Source: NOAA

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How to be a survivor

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Lahaina Miracle House, pre-renovation

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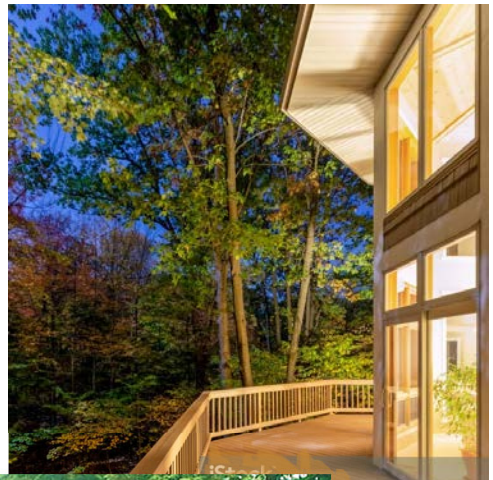
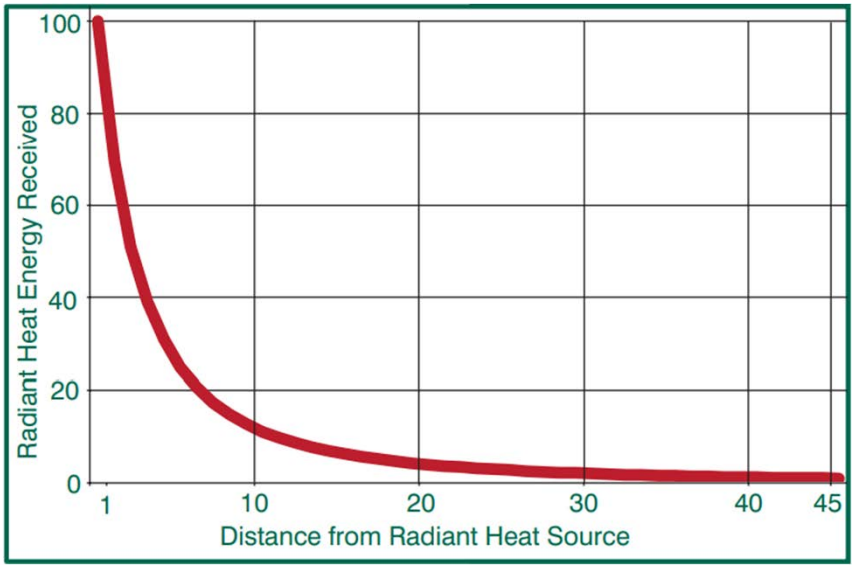
Lahaina Miracle House, post-renovation

Why defensible space matters

Beautiful but deadly





The first few feet from the fire are by far the hottest.

Burning trees next to the house can cause intense heat that can radiate through windows and catch curtains on fire *inside the house*.

Establish Defensible Space

Immediate Zone: 0 - 5 feet "Fuel-Free Zone"

- No combustibles, no branches

Intermediate Zone: 5 - 30 feet, "Clean and Green"

- 1-3 trees, branches 18 feet apart
- Remove ladder fuels – no shrubs under trees, no branches below 10 feet
- Watered lawn, noncombustible ground cover

Extended Zone: 30 - 100 feet, "Reduced Fuel Zone"

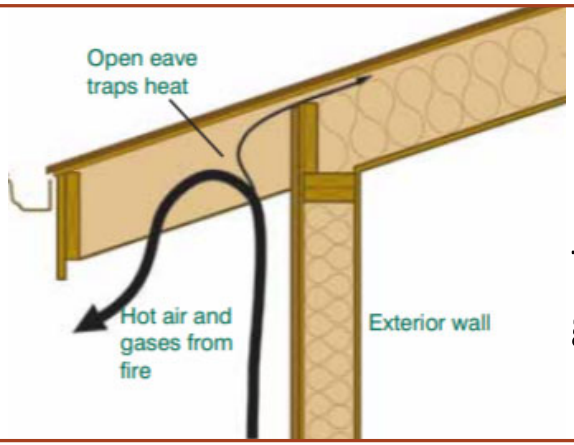
- 30 to 60 feet: Tree canopies 12 feet apart
- 60 to 100 feet: Tree canopies 6 feet apart
- Trim branches back 10 feet from access roads

Beyond 100 feet:

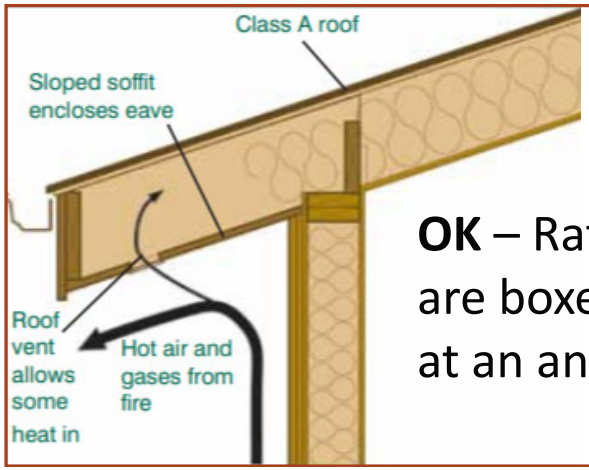
- Thin trees; prune ladder fuels
- Employ fuel breaks – strips of water, grass, or rock

Why construction techniques matter

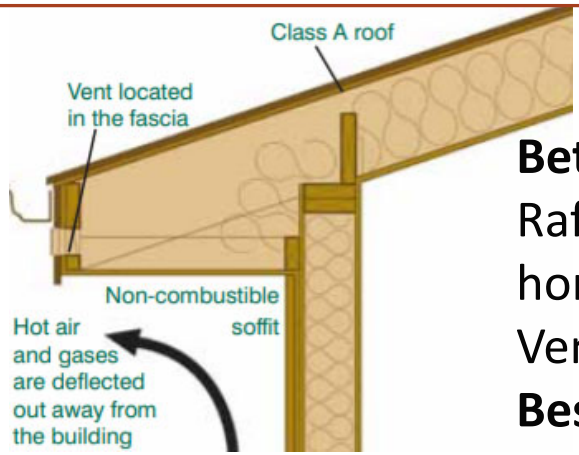
This is a fire trap



Bad –
Embers are carried up the wall by hot air and get trapped in open rafters.



OK – Rafters are boxed in at an angle



Better –
Rafters are boxed in horizontal.
Vent is moved to fascia.
Best – Unvented Attic!

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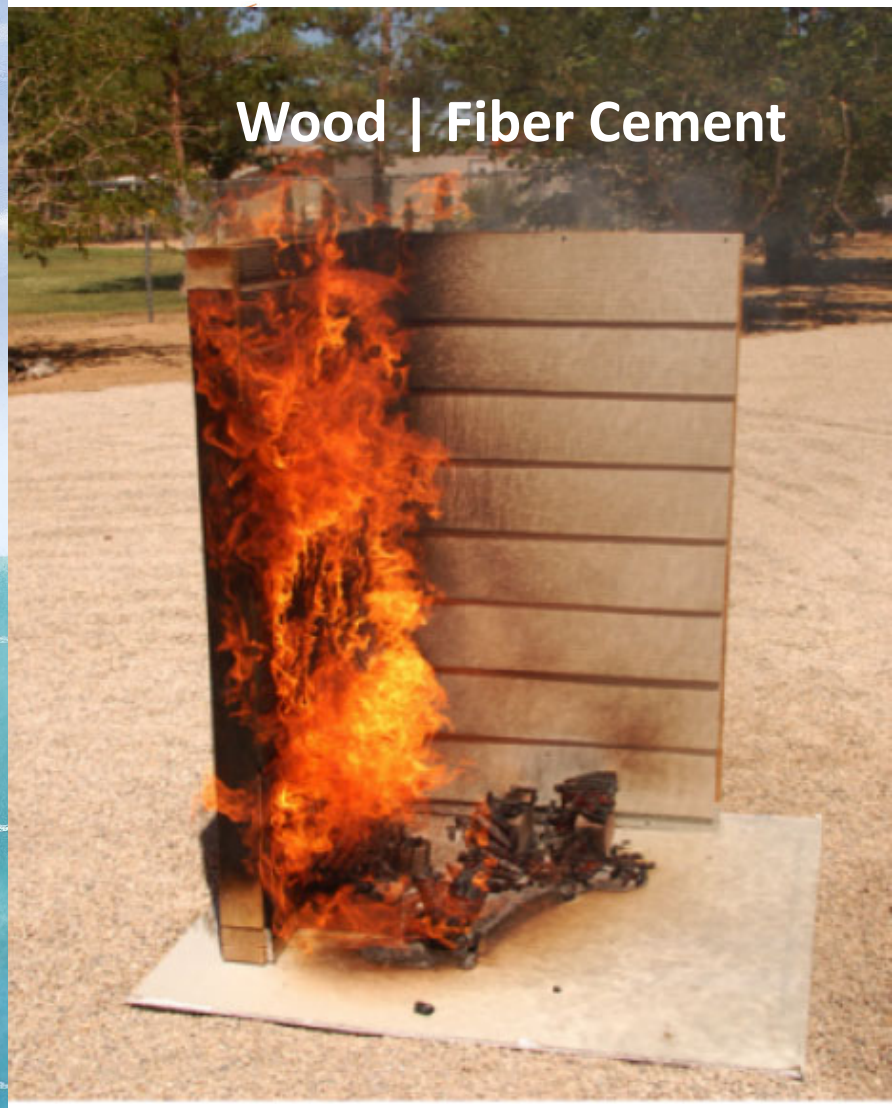
Construction Choices: How not to feed the fire

This home survived a fire that claimed more than 400 neighboring homes, thanks to

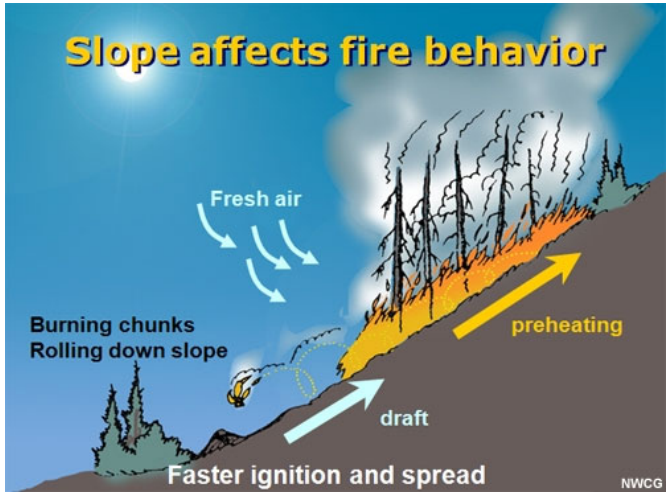
- a fire-resistant tile roof
- stucco exterior
- double-pane windows
- stucco-covered boxed eaves
- boxed-in decks



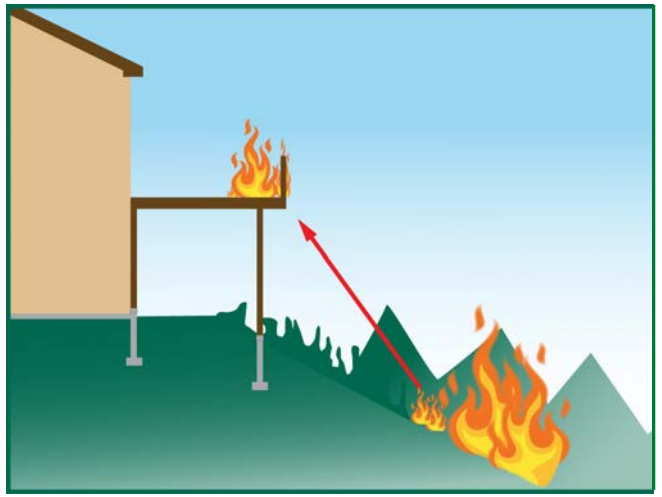
Why materials choices matter

Source: IBHS

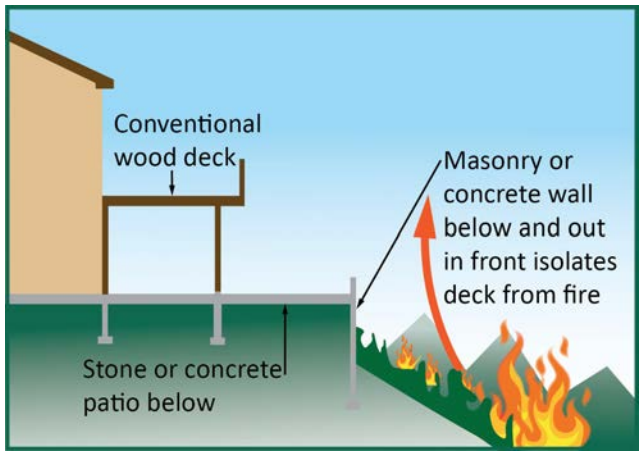
Wildfires – Fire-Resistant Decks



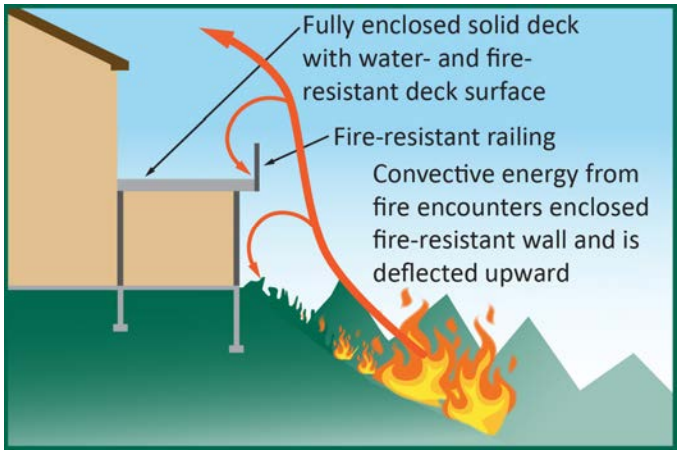
Fire moves up hill 6x-8x times faster



Decks above slopes are at risk



Build a patio or masonry wall below the deck.



Enclose the area under the deck.

Source: Colorado State Forest Service

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Pop Quiz – What's wrong with this deck?

Beautiful but deadly

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Pop Quiz – What did this builder do right?

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Winter Weather

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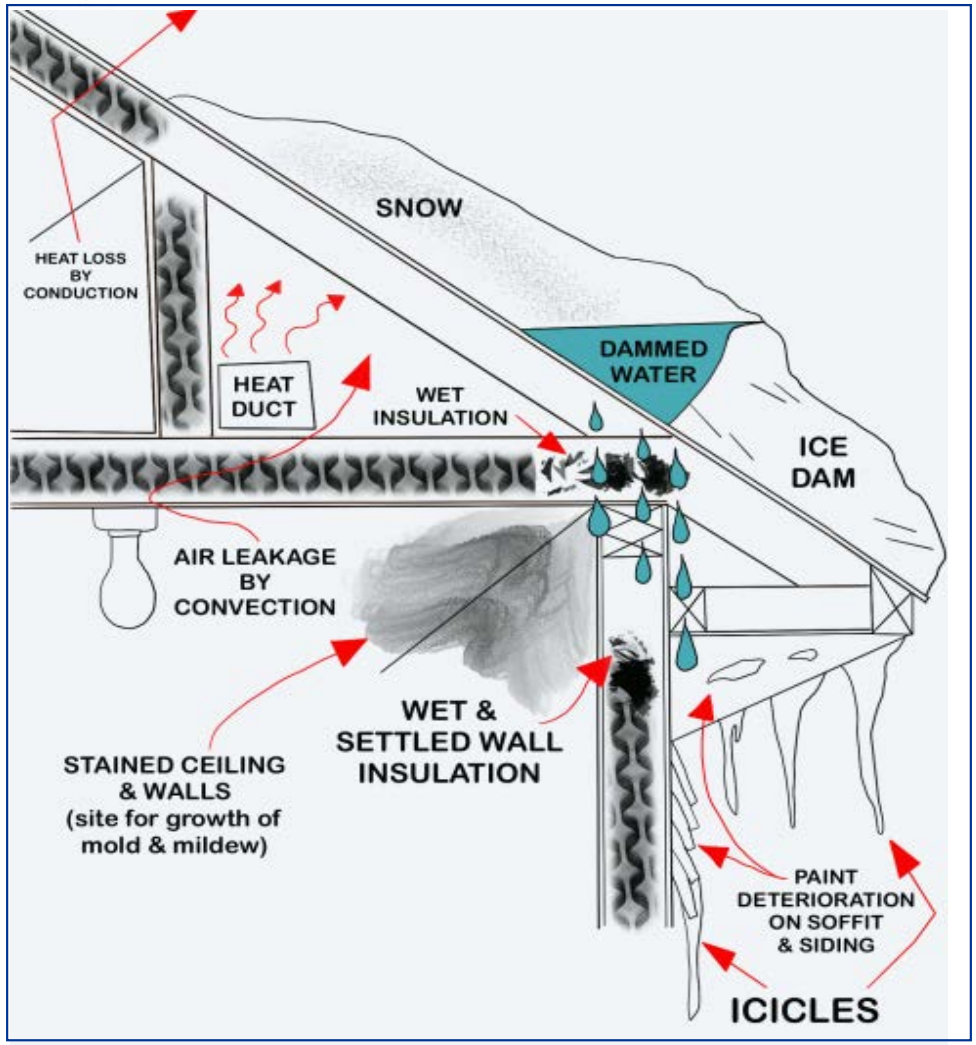
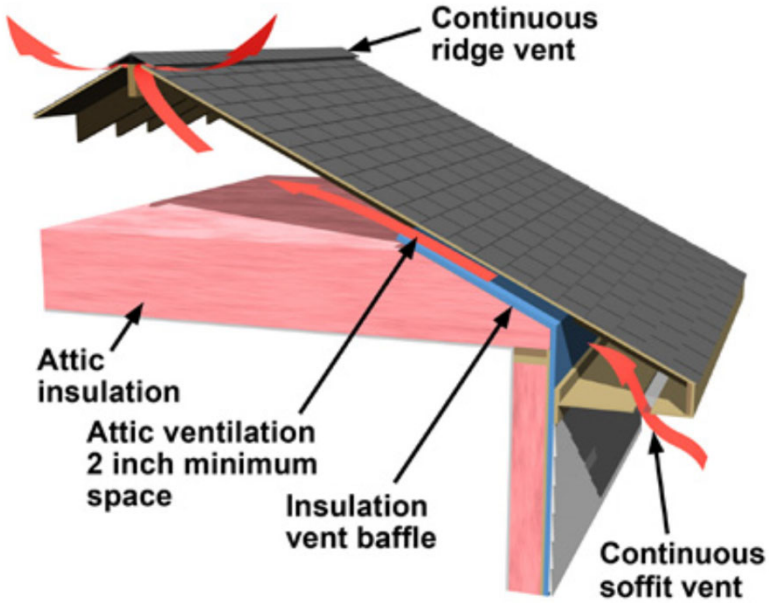
Preventing Ice Dams –
the Winter Weather Challenge for Builders

Ice Dams: Problem … Solved





Prevent Ice Dams with

- Air sealing
- Insulation
- Attic Ventilation

Winter Weather – More Helps

- Install triple-pane windows to stay warmer and stop condensation.
- Insulate and airseal to 2021 IECC levels
- Use water-resistant siding and flooring.
- Install a cold-climate heat pump.
- Install freeze-protected outside faucets.
- Consider PV + battery, instead of gas generators.

Source: UMinn

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Extreme Heat

Source: University of Arizona

Extreme Heat

- Codes don’t address Extreme Heat directly

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Extreme Heat

- Codes don’t address Extreme Heat directly
- …Yet our homes are our best defense
  - Air-conditioning
  - Air filtration
  - Fans
  - Refrigeration
  - Water
  - Shade
  - Thermal regulation

Source: University of Arizona

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  - Thermal regulation
    - (Mass, operable windows, insulation, air-sealing)

Source: University of Arizona

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  - **Hours of Safety**

Source: University of Arizona

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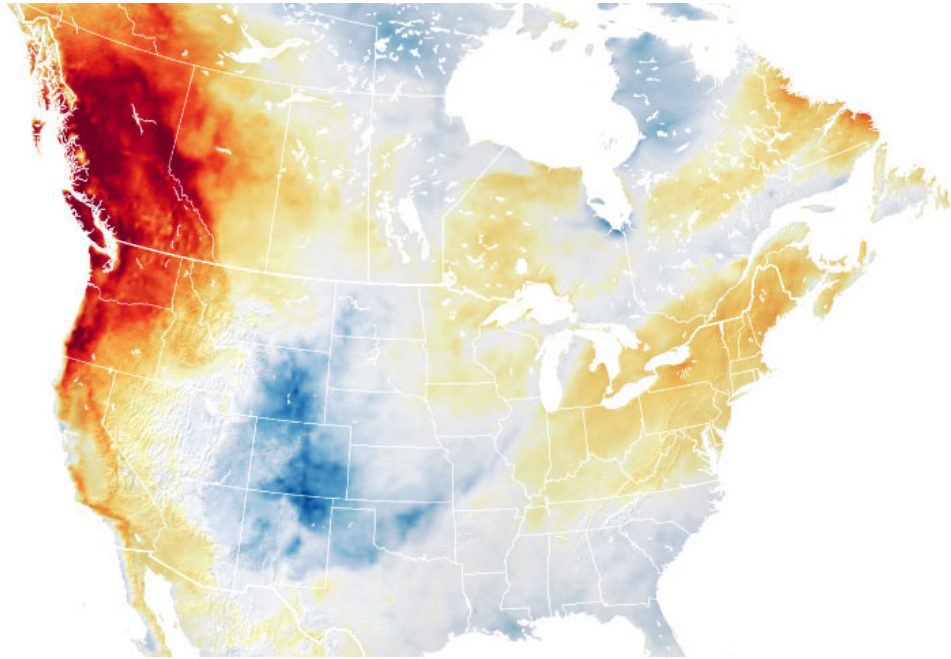
  - **Hours of Safety**

Source: University of Arizona

Extreme Heat

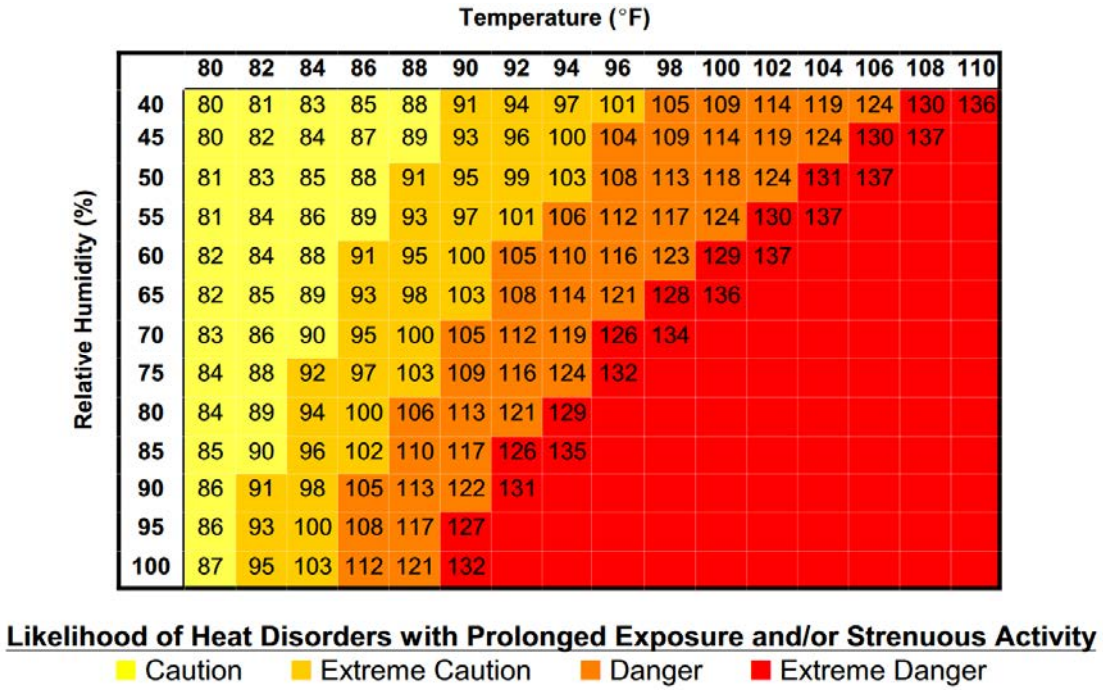
- Study led by U of Oregon
  - Question: How could shading and night ventilation have prevented heat-related deaths during the 2021 Pacific Northwest Heat Wave?



Source: https://earthobservatory.nasa.gov/images/148506/exceptional-heat-hits-pacific-northwest

Extreme Heat

- Study led by U of Oregon
  - Question: How could shading and night ventilation have prevented heat-related deaths?
- Metric: NOAA Heat Index
  - Caution
  - Extreme Caution
  - Danger
  - Extreme Danger



Source: www.noaa.gov/jetstream/synoptic/heat-index

Extreme Heat

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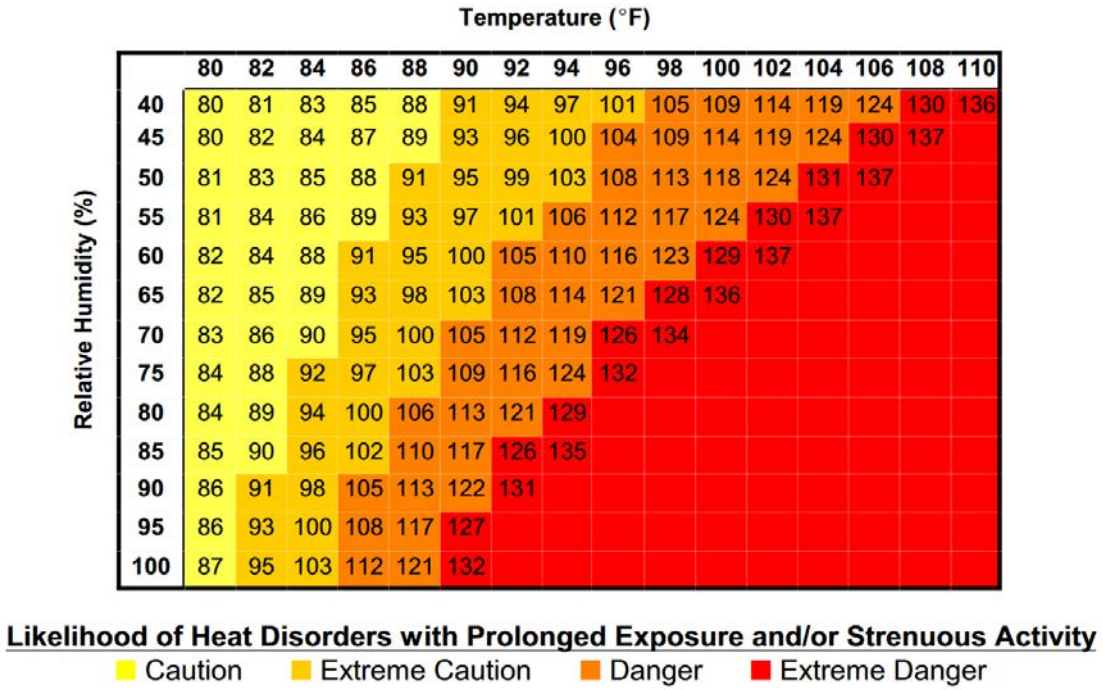
- Metric: NOAA Heat Index
  - Caution
  - Extreme Caution
  - Danger
  - Extreme Danger
- Shading types
  - Roller shades
  - Insulating cellular shades
  - Exterior shutters



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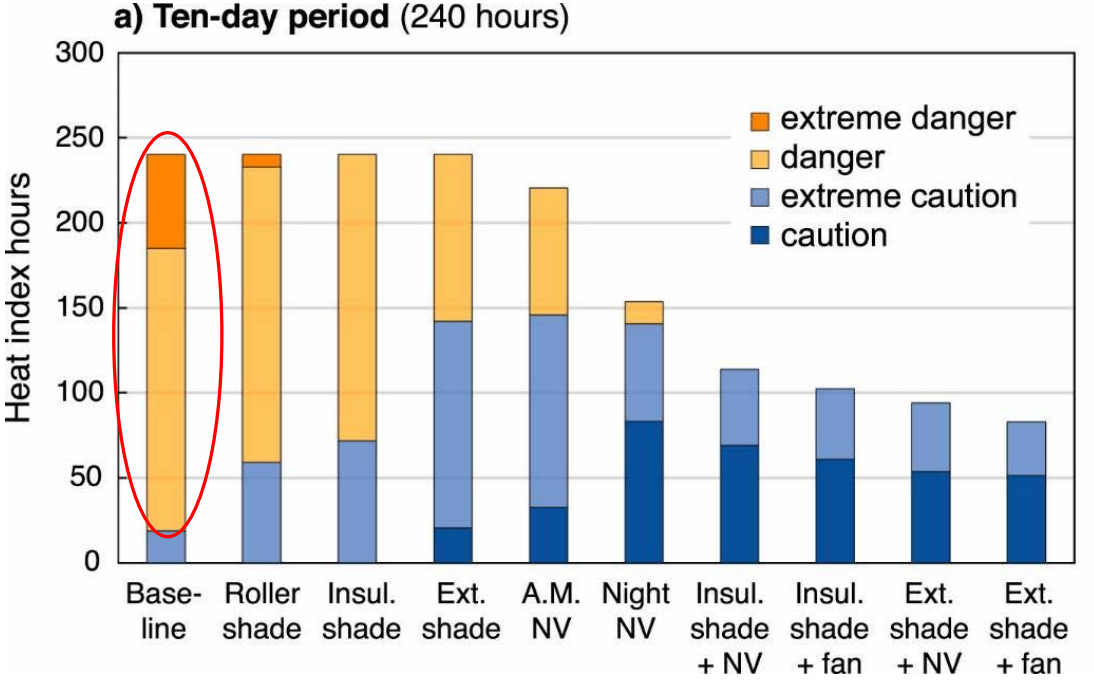
Extreme Heat

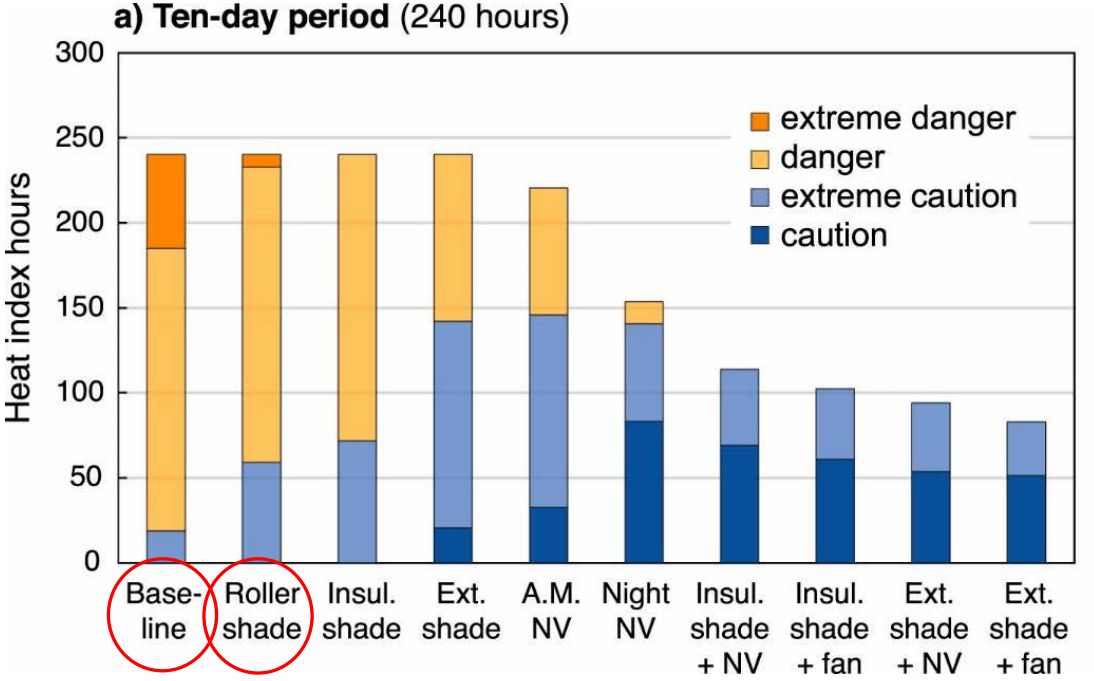
- Reduction in ‘danger’ and ‘extreme danger’ hours:



Source: Rempel, et a., 2022
https://www.sciencedirect.com/science/article/pii/S0306261922006729?via%3Dihub#sec2.2

Extreme Heat

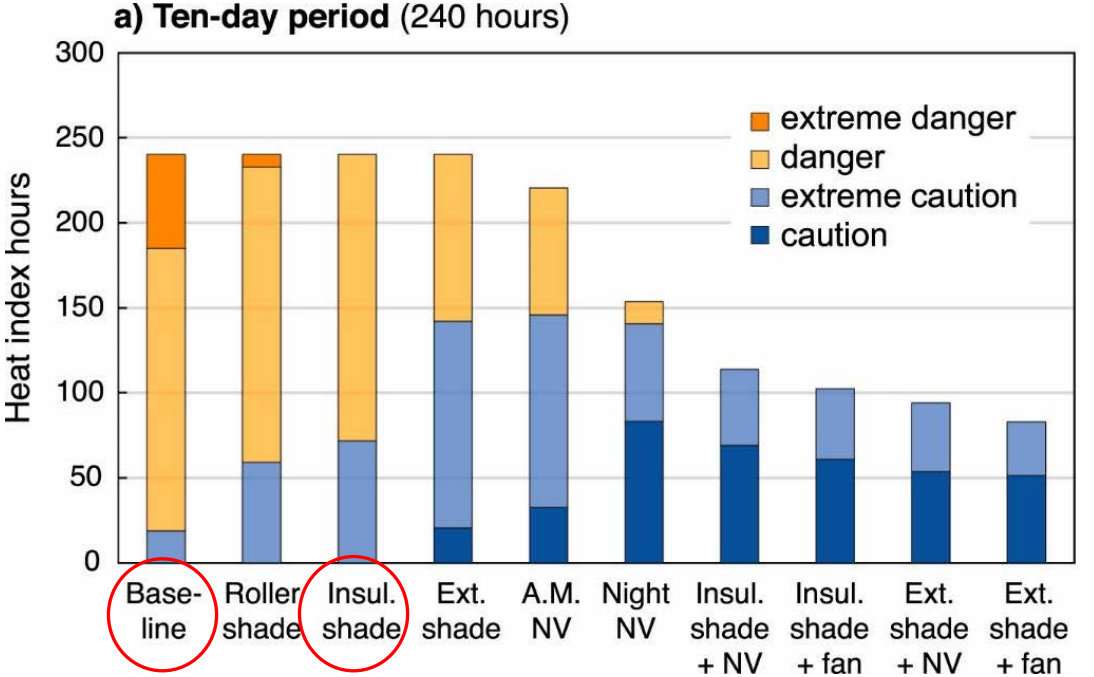
- Reduction in ‘danger’ and ‘extreme danger’ hours:
  - Roller Shades: **18%**



Source: Rempel, et a., 2022
https://www.sciencedirect.com/science/article/pii/S0306261922006729?via%3Dihub#sec2.2

Extreme Heat

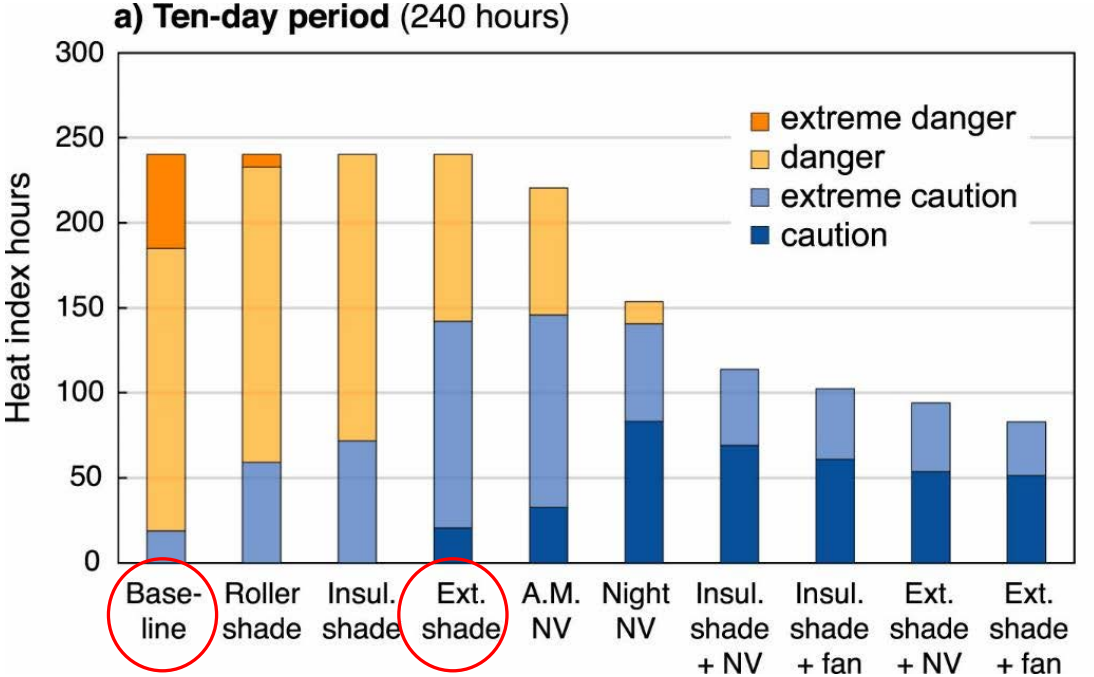
- Reduction in ‘danger’ and ‘extreme danger’ hours:
  - Roller Shades: 18%
  - Cellular shades: **23%**



Source: Rempel, et a., 2022
https://www.sciencedirect.com/science/article/pii/S0306261922006729?via%3Dihub#sec2.2

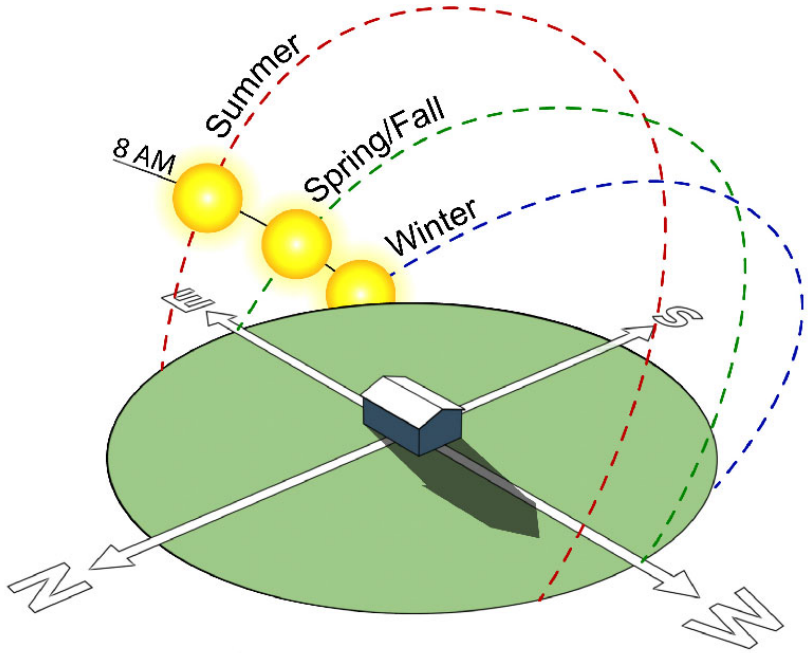
Extreme Heat

- Reduction in ‘danger’ and ‘extreme danger’ hours:
  - Roller Shades: 18%
  - Cellular shades: 23%
  - Exterior shutters: **55%**



Source: Rempel, et a., 2022
https://www.sciencedirect.com/science/article/pii/S0306261922006729?via%3Dihub#sec2.2

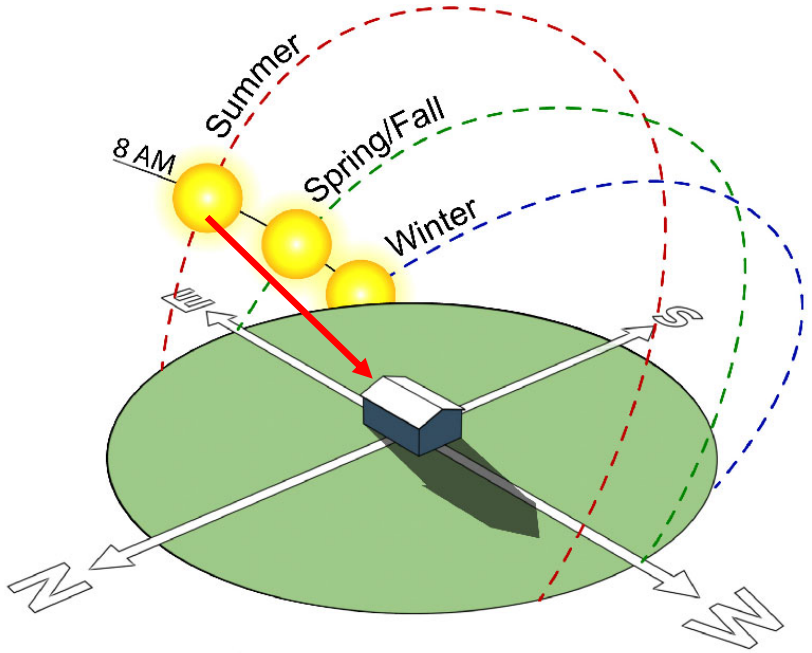
Characteristics of Sunlight



Source: http://www.fsec.ucf.edu/en/about/index.htm

Characteristics of Sunlight

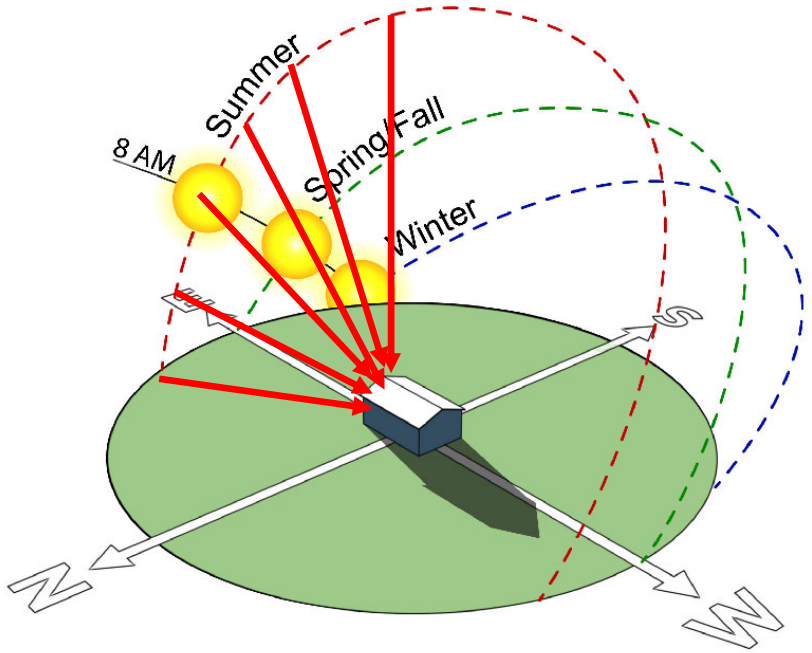
- E/W
  - Low angles = direct sun



Source: http://www.fsec.ucf.edu/en/about/index.htm

Characteristics of Sunlight

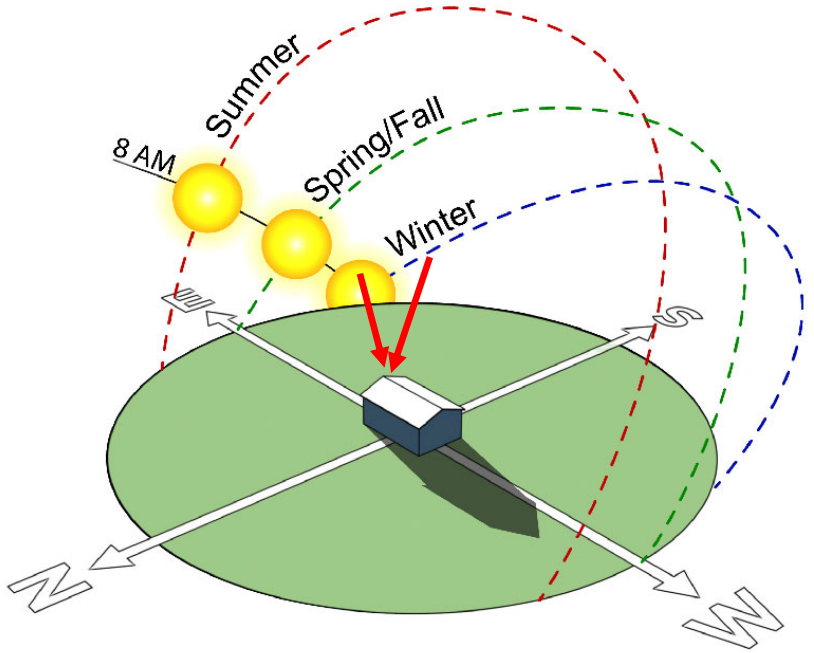
- E/W
  - Low angles = direct sun
  - Hours of exposure increase in summer



Source: http://www.fsec.ucf.edu/en/about/index.htm

Characteristics of Sunlight

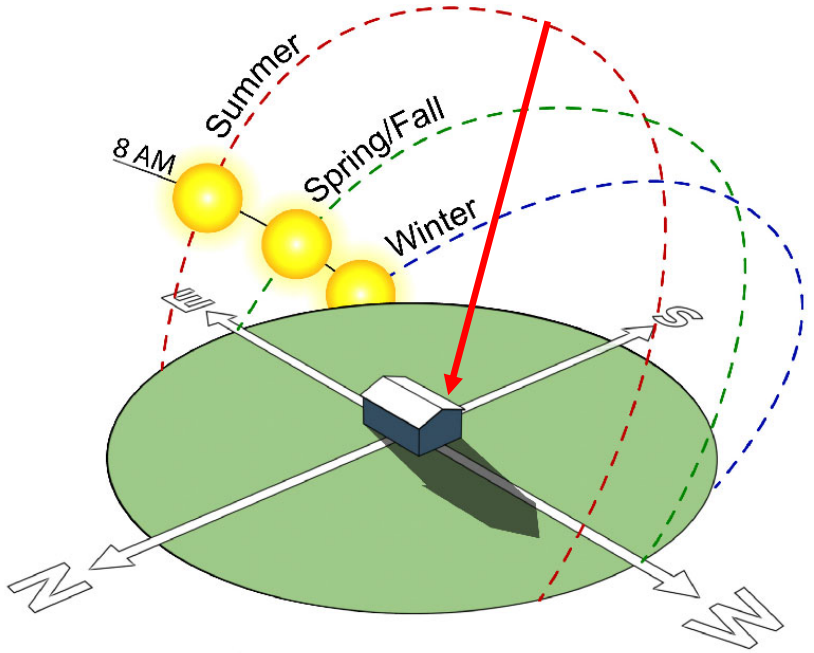
- E/W
  - Low angles = direct sun
  - Hours of exposure increase in summer



Source: http://www.fsec.ucf.edu/en/about/index.htm

Characteristics of Sunlight

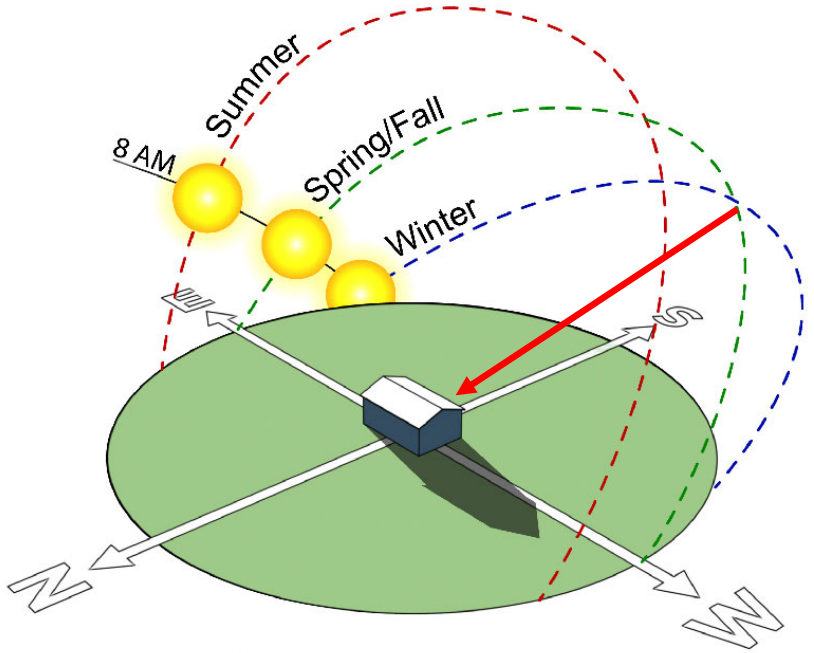
- E/W
  - Low angles = direct sun
  - Hours of exposure increase in summer
- South
  - High angles in summer



Source: http://www.fsec.ucf.edu/en/about/index.htm

Characteristics of Sunlight

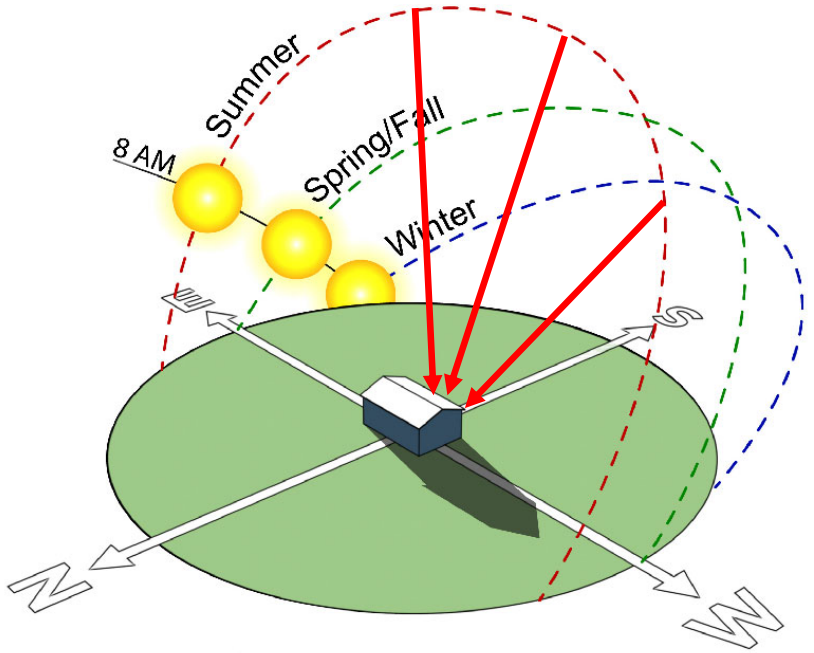
- E/W
  - Low angles = direct sun
  - Hours of exposure increase in summer
- South
  - High angles in summer
  - Low angles in winter



Source: http://www.fsec.ucf.edu/en/about/index.htm

Characteristics of Sunlight

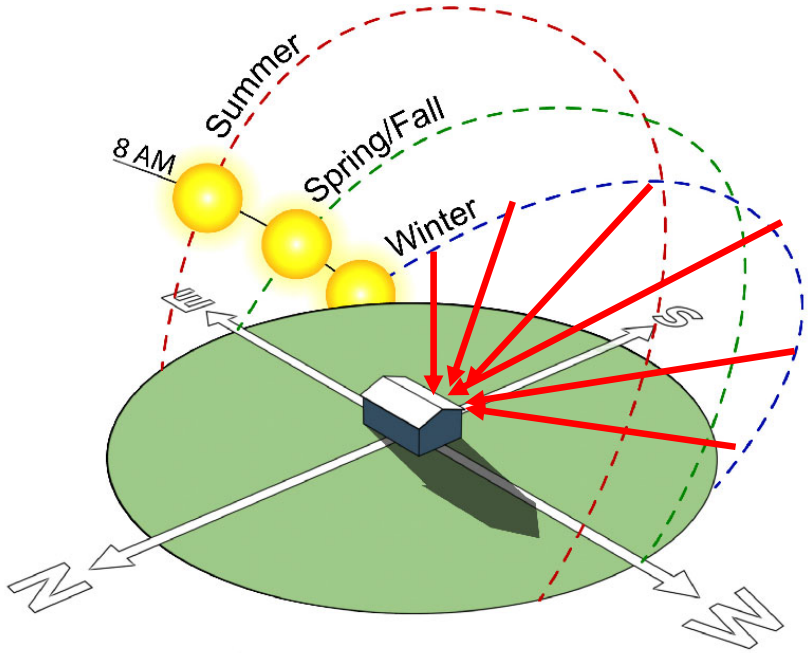
- E/W
  - Low angles = direct sun
  - Hours of exposure increase in summer
- South
  - High angles in summer
  - Low angles in winter
  - Hours of exposure decrease in summer



Source: http://www.fsec.ucf.edu/en/about/index.htm

Characteristics of Sunlight

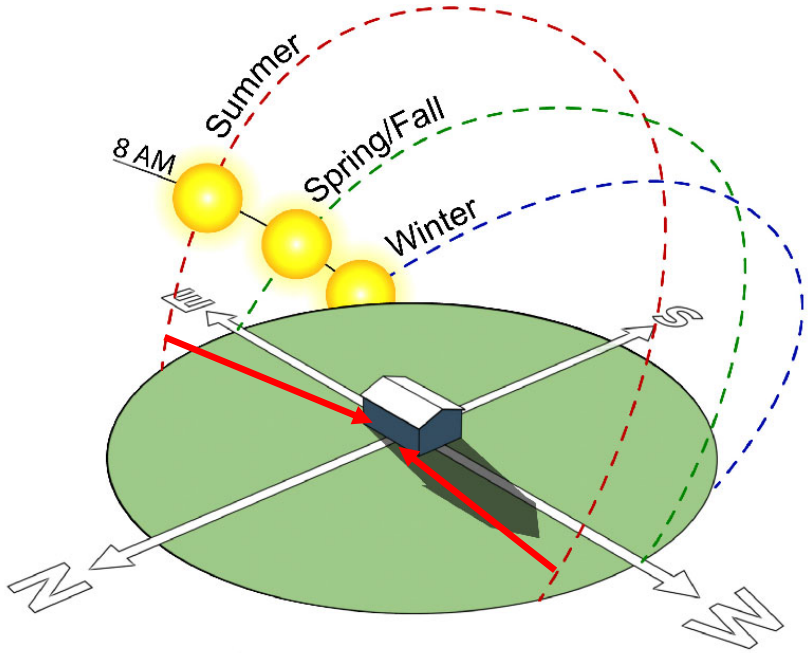
- E/W
  - Low angles = direct sun
  - Hours of exposure increase in summer
- South
  - High angles in summer
  - Low angles in winter
  - Hours of exposure decrease in summer



Source: http://www.fsec.ucf.edu/en/about/index.htm

Characteristics of Sunlight

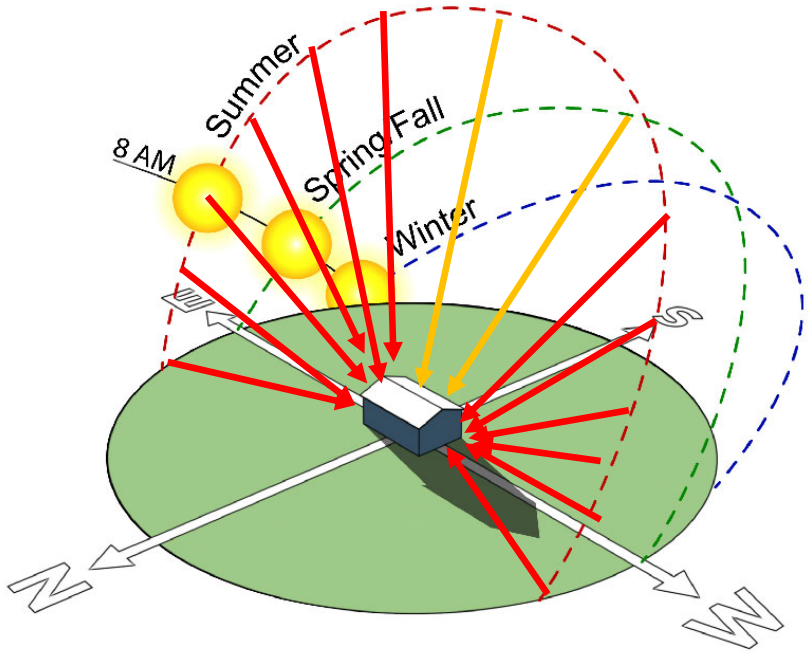
- E/W
  - Low angles = direct sun
  - Hours of exposure increase in summer
- South
  - High angles in summer
  - Low angles in winter
  - Hours of exposure decrease in summer
- North
  - Glancing side angles
  - Exposure in summer only



Source: http://www.fsec.ucf.edu/en/about/index.htm

Characteristics of Sunlight

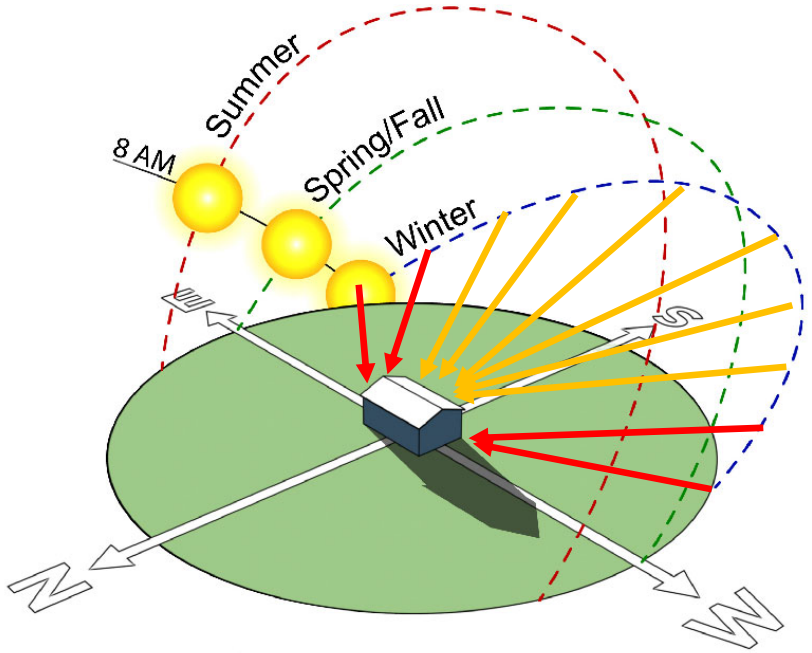
- Summer, 36°N Latitude
  - 2 hrs within 45° of South
  - 6 hrs within 45° of West



Source: http://www.fsec.ucf.edu/en/about/index.htm

Characteristics of Sunlight

- Summer, 36°N Latitude
  - 2 hrs within 45° of South
  - 6 hrs within 45° of West
- Winter, 36°N Latitude
  - 6 hrs within 45° of South
  - 2 hrs within 45° of West



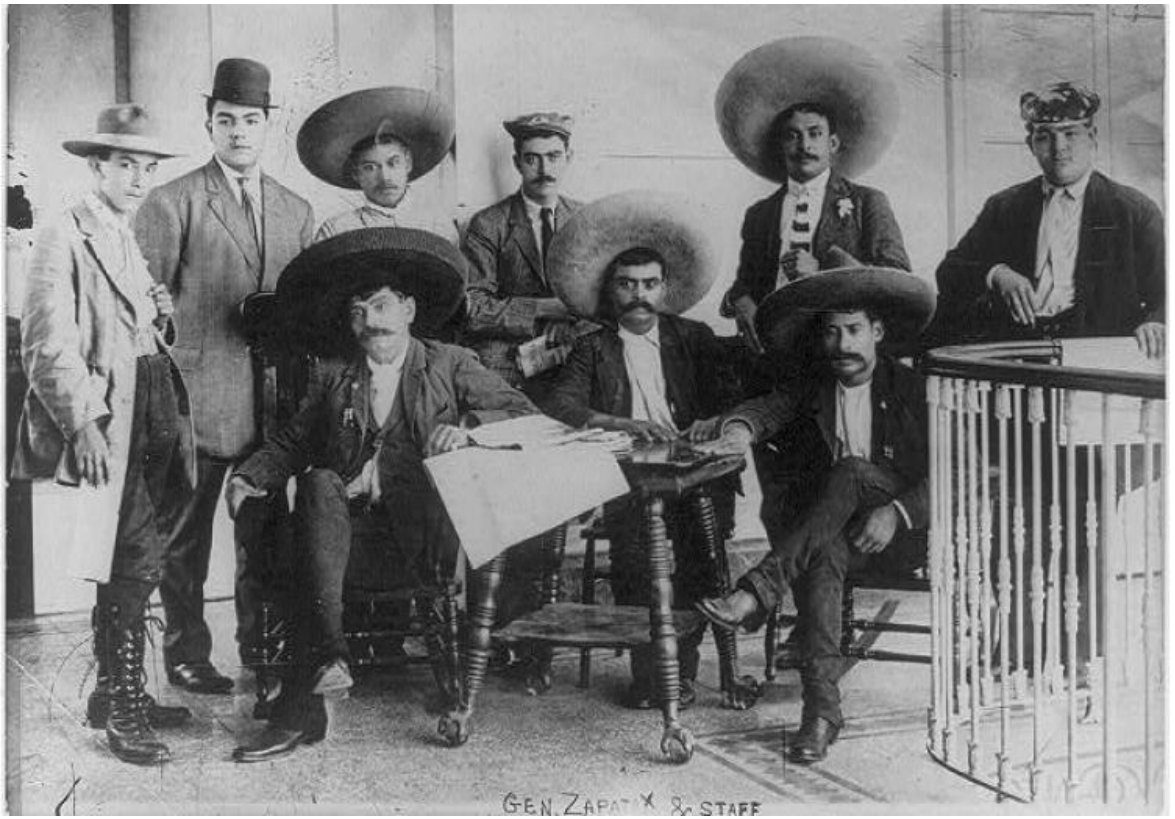
Source: http://www.fsec.ucf.edu/en/about/index.htm

Methods of Shading

Pre-Assessment Quiz

Methods of Shading

Q:
Which leaders of the Mexican Revolution had the best understanding of shading?

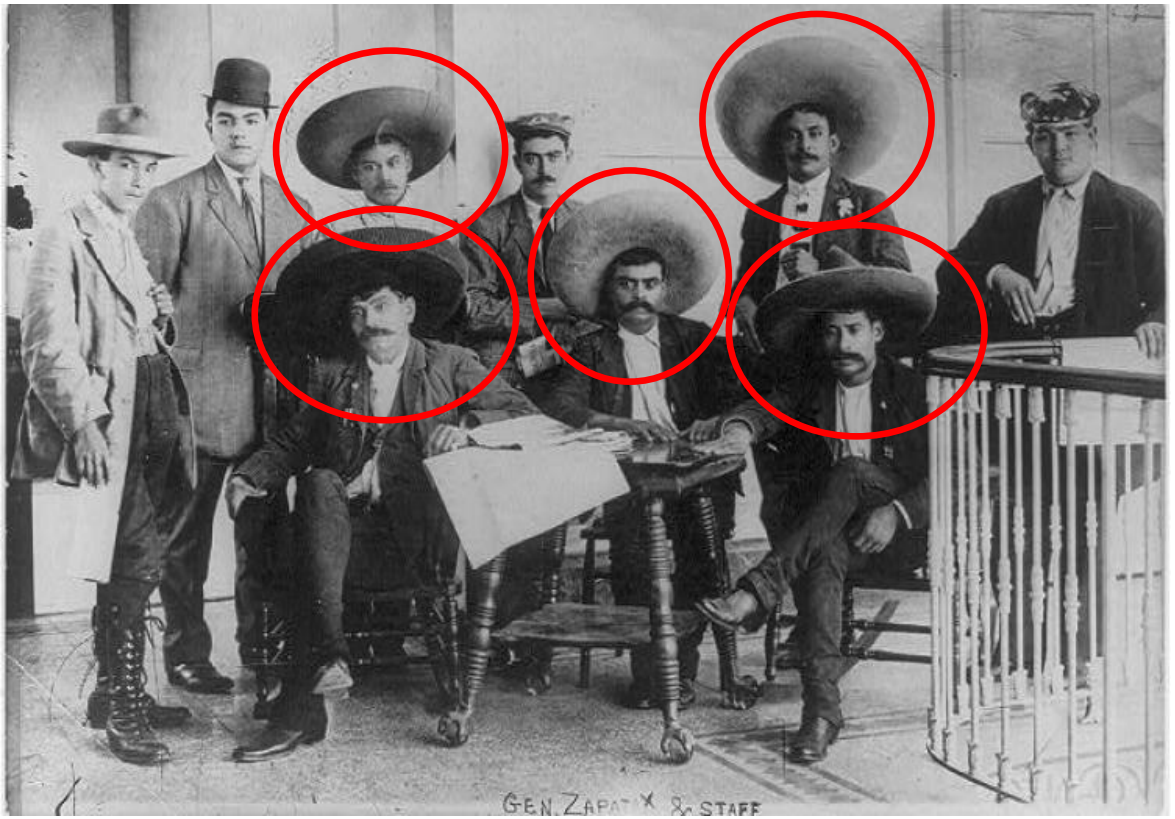


Source: National Endowment for the Humanities https://edsitement.neh.gov/lesson-plans/mexican-revolution

Methods of Shading

Q:
Which leaders of the Mexican Revolution had the best understanding of shading?

A:
General Zapata and several of his staff…



Source: National Endowment for the Humanities https://edsitement.neh.gov/lesson-plans/mexican-revolution

Methods of Shading

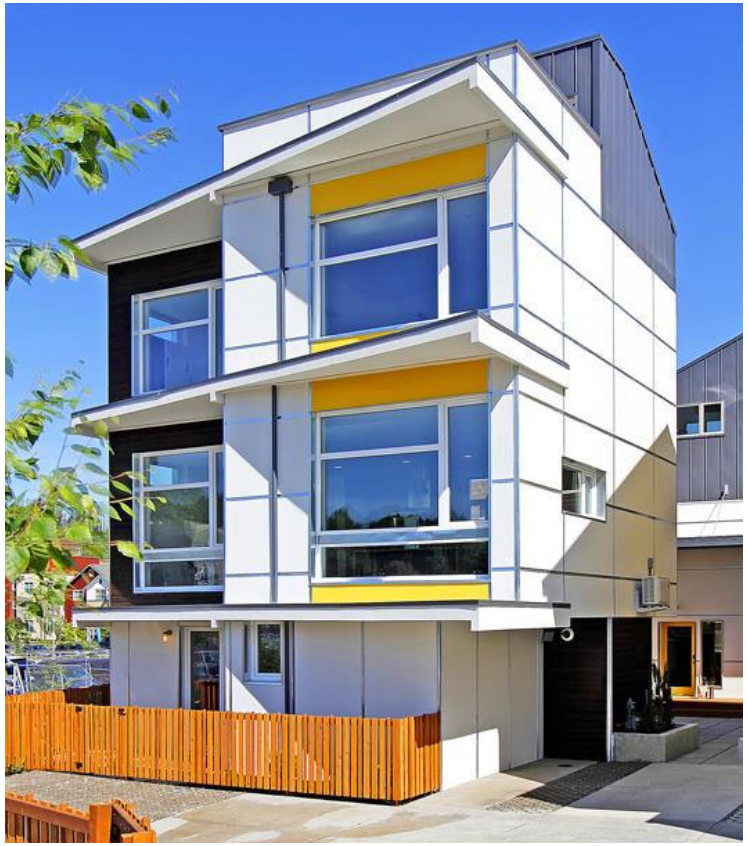
Q:
Which leaders of the Mexican Revolution had the best understanding of shading?

A:
General Zapata and several of his staff…

…but not this gentleman.

Source: National Endowment for the Humanities https://edsitement.neh.gov/lesson-plans/mexican-revolution

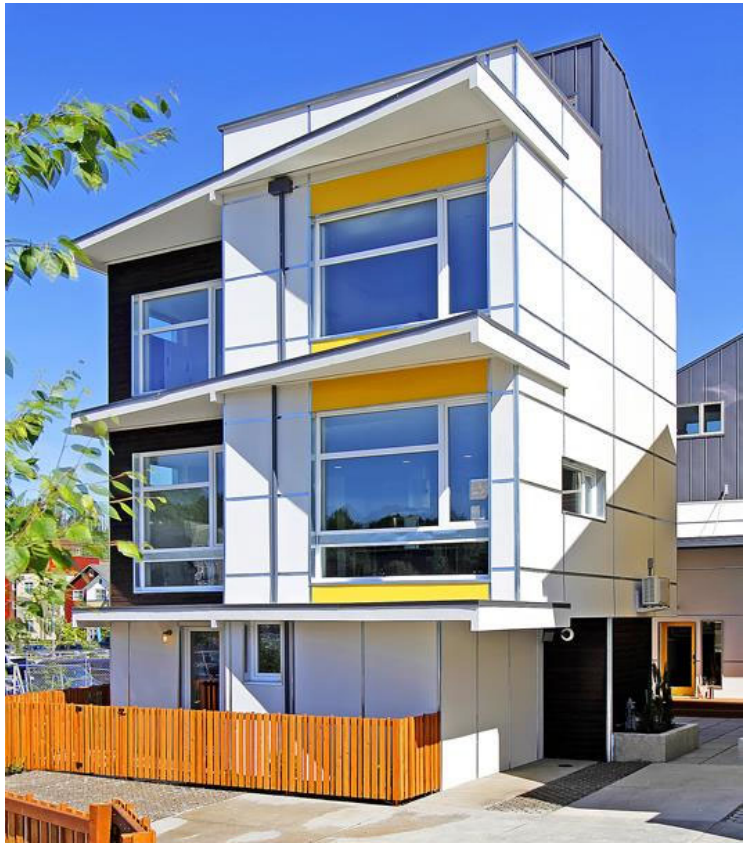
Shading in New Construction



Source: https://www.dwelldevelopment.com/

Shading in New Construction

- Architectural shading
- Exterior attachments
- Interior attachments
- Landscape shading



Source: https://www.dwelldevelopment.com/

Shading in New Construction

- Architectural shading
  - Roof eaves
  - Window overhangs
  - Porch roofs
  - 2nd story decks
  - Wing walls
  - Stepped walls
  - Side fins

Source: https://www.osti.gov/biblio/763375/

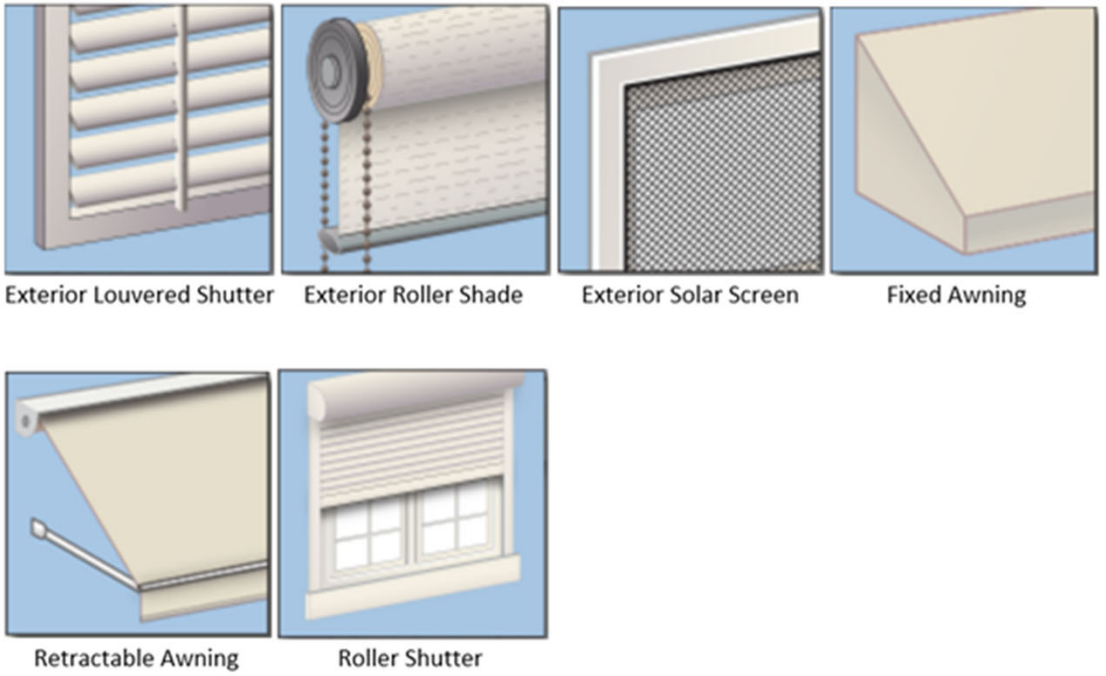
Source: https://www.dwelldevelopment.com/

Source: https://www.sbse.org/resources/climate-consultant

Source: https://burnsvillemn.gov/DocumentCenter/View/20306/Solar-Handout?bidId=

Shading in New Construction

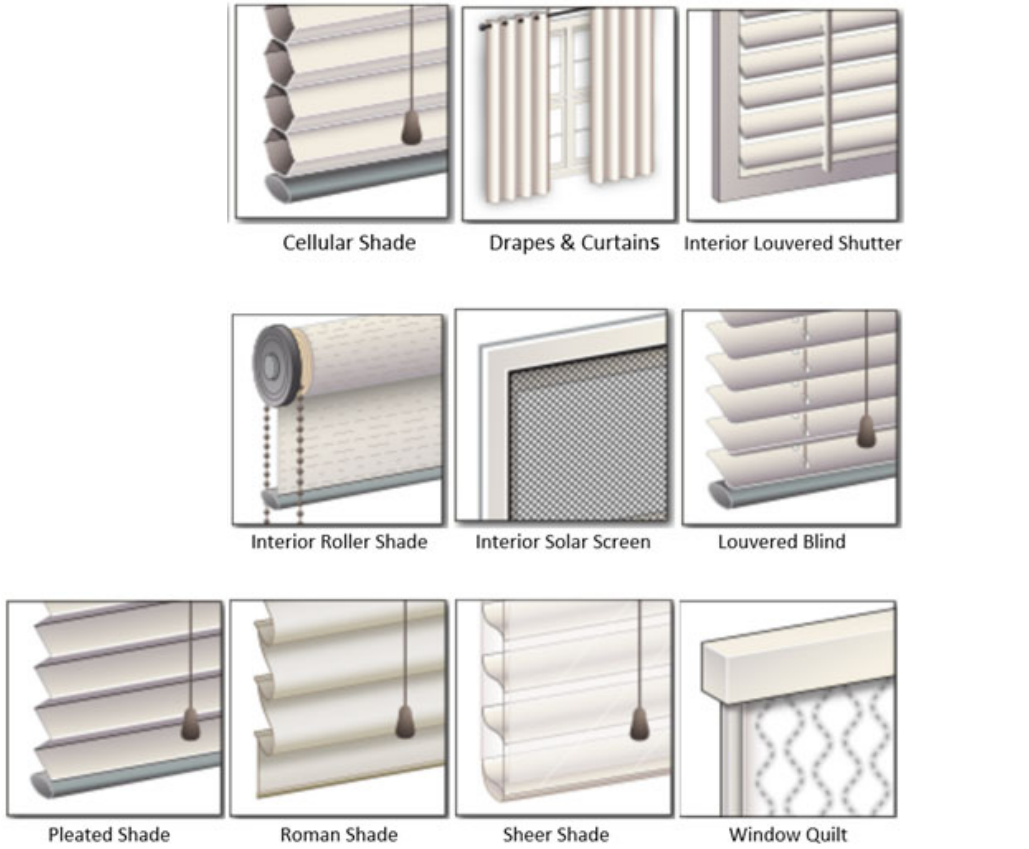
- Exterior attachments
  - Louvered shutters
  - Roller shades and
  - Roller shutters
  - Solar screens
  - Awnings



Source: https://efficientwindowcoverings.org/

Shading in New Construction

- Interior attachments
  - Cellular shades
  - Drapes
  - Shutters
  - Roller shades
  - Solar screens
  - Blinds
  - Other shades (pleated, Roman, sheer)



Source: https://efficientwindowcoverings.org/

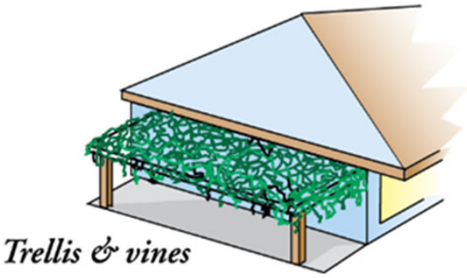
Shading in New Construction

- Landscape shading
  - Trellises
  - Pergolas
  - Shade trees
  - Shrubs
  - Tall annuals

Source: PNNL

Source: PNNL

Source: PNNL



Source: http://www.fsec.ucf.edu/en/about/index.htm/

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Shading Strategies for N, S, E, W

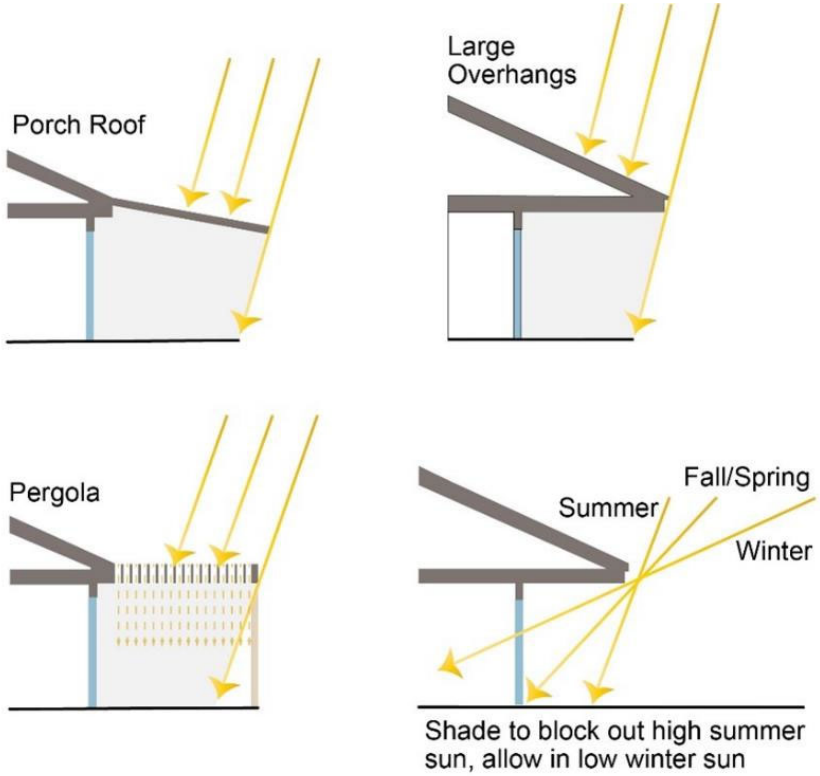
South-facing Windows

- Horizontal shading
  - Roof eaves
  - Window overhangs
  - Awnings
  - Porch roofs
  - Pergolas

Source: http://www.fsec.ucf.edu/en/about/index.htm

South-facing Windows

Source: https://burnsvillemn.gov/DocumentCenter/View/20306/Solar-Handout?bidId=



Source: https://www.sbse.org/resources/climate-consultant

East/West-facing Windows

- Horizontal shading + Vertical front shading
  - Roof eaves
  - Window overhangs
  - Awnings
  - Porch roofs
  - Pergolas

Source: https://www.aoml.noaa.gov/hrd/shutters/index3.html

East/West-facing Windows

- Horizontal shading + Vertical front shading
  - Roof eaves
  - Window overhangs
  - Awnings
  - Porch roofs
  - Pergolas

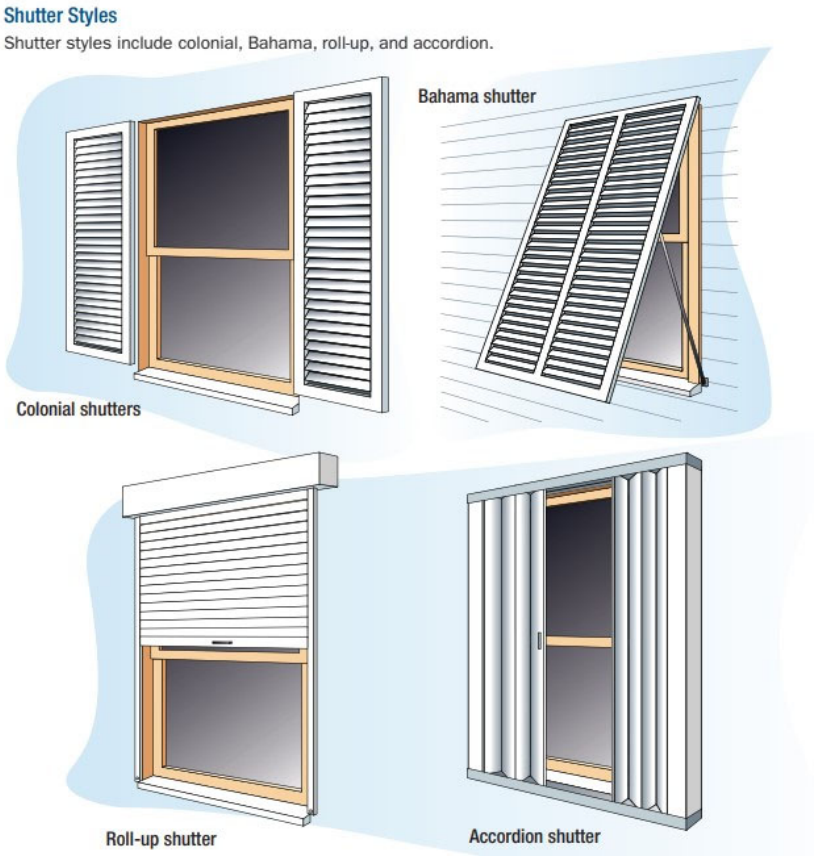
  +

  - Interior attachments
    - Shades, shutters, blinds, etc.
  - Exterior attachments
    - Rolldown shutters, Bahama shutters

Source: https://www.aoml.noaa.gov/hrd/shutters/index3.html

East/West-facing Windows

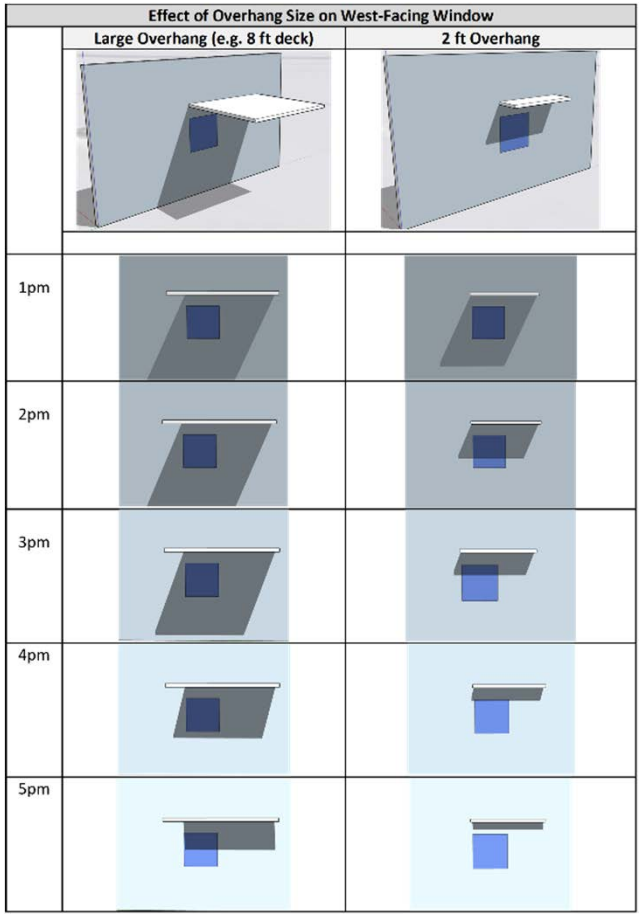
Source: https://www.solardecathlon.gov/



Source: www.fema.gov/sites/default/files/2020-08/fema499_2010_edition.pdf

East/West-facing Windows

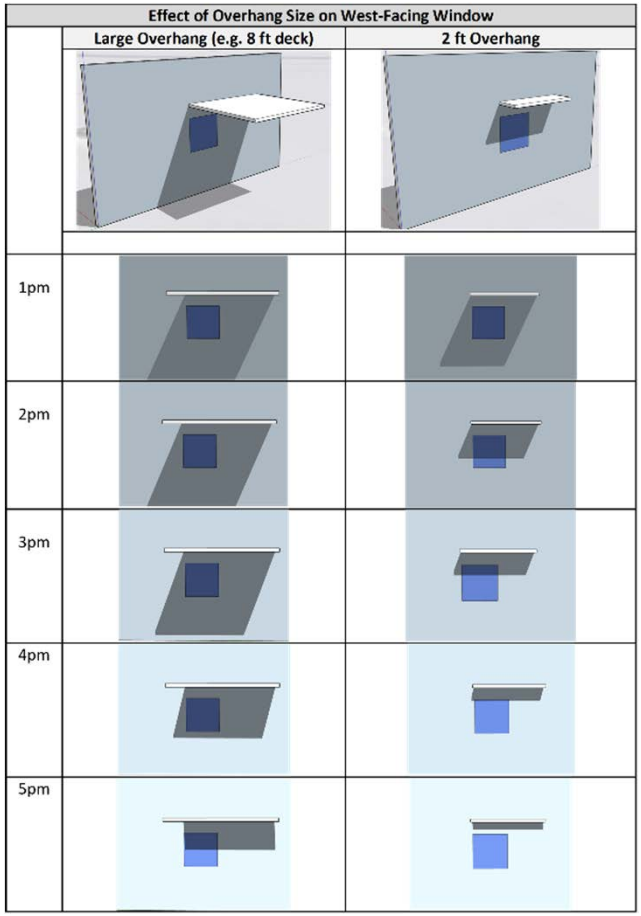
- Large vs ‘normal’ overhangs on E/W windows
- On E/W, more shade in summer = more shade in winter



Source: PNNL

East/West-facing Windows

- Large vs ‘normal’ overhangs on E/W windows
- On E/W, more shade in summer = more shade in winter
- Vertical front shading still needed!

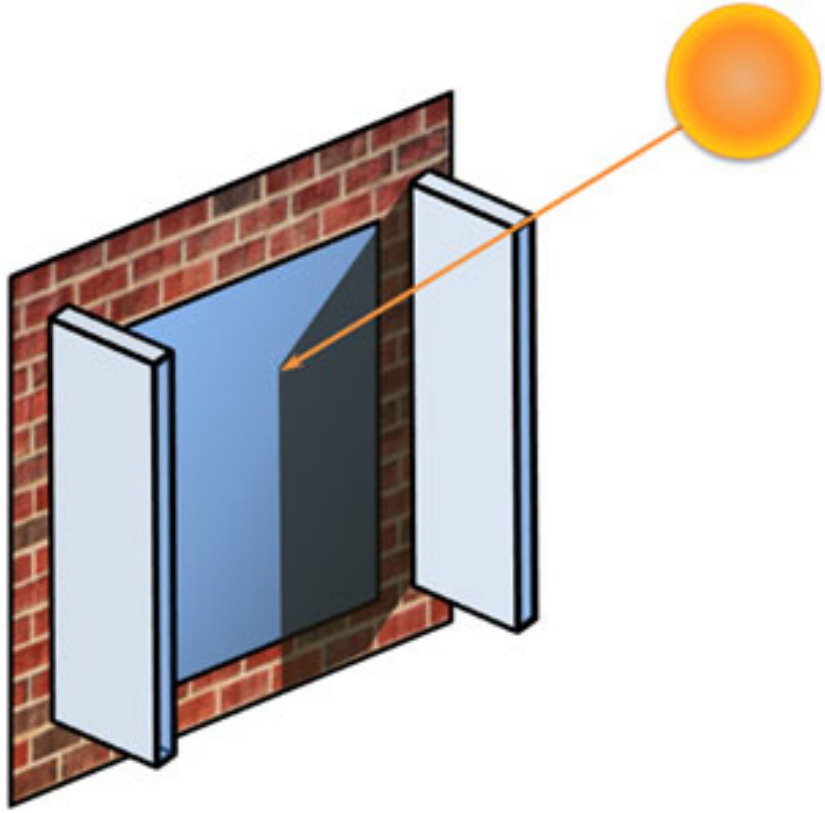


Source: PNNL

North-facing Windows

- Vertical side shading
  - Side fins
  - Wing walls
  - Stepped walls

- Vertical front shading
  - Interior attachments
    - Shades, shutters, blinds, etc.
  - Exterior attachments
    - Rolldown shutters, Bahama shutters



Source: https://www.lbl.gov/

What You Can Do: Action Items

1. Design roof eaves, porches, etc. with shading in mind
    1. Especially E/W walls
2. Plan for interior or exterior attachments
    1. Pre-wire for automation
    2. Work w/ architect and/or interior designer to merge function with aesthetic
3. Learn more and devise a plan…

Source: PNNL

Window Shading Resources

- Building America Solution Center (www.basc.pnnl.gov)
  - Shading and Solar Control for Windows and Skylights (www.basc.pnnl.gov/resource-guides/shading-and-solar-control-windows-and-skylights)
  - Window Attachments for Solar Control and Energy Efficiency (https://basc.pnnl.gov/resource-guides/window-attachments-solar-control-and-energy-efficiency)
- Attachments Energy Rating Council (www.aerc.org)
- Efficient Window Coverings (www.efficientwindowcoverings.org)
- Solar Radiation Data Manual for Buildings (www.nrel.gov/docs/legosti/old/7904.pdf)

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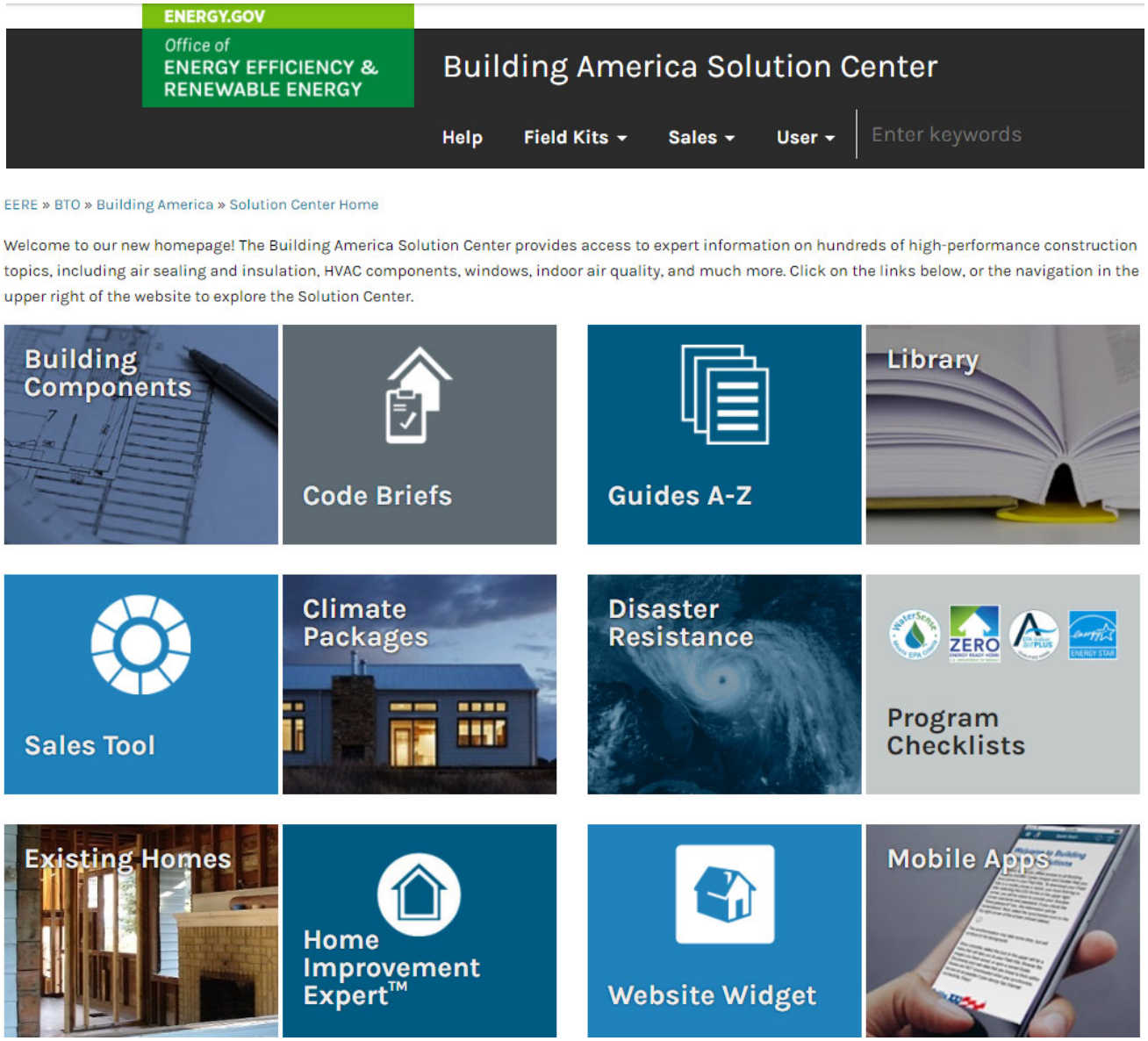
Building America Solution Center
(basc.pnnl.gov)



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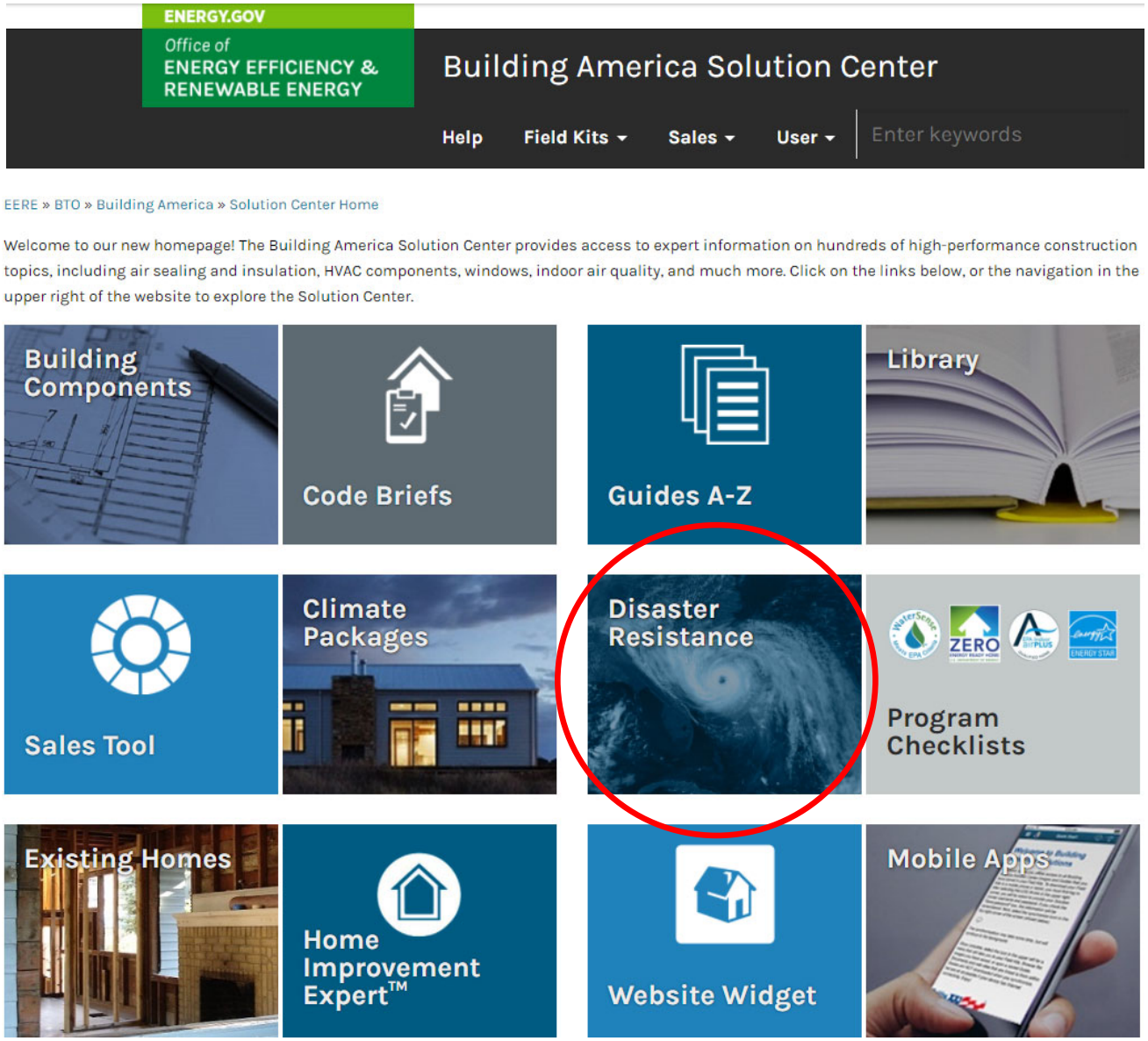
Building America Solution Center
(basc.pnnl.gov)



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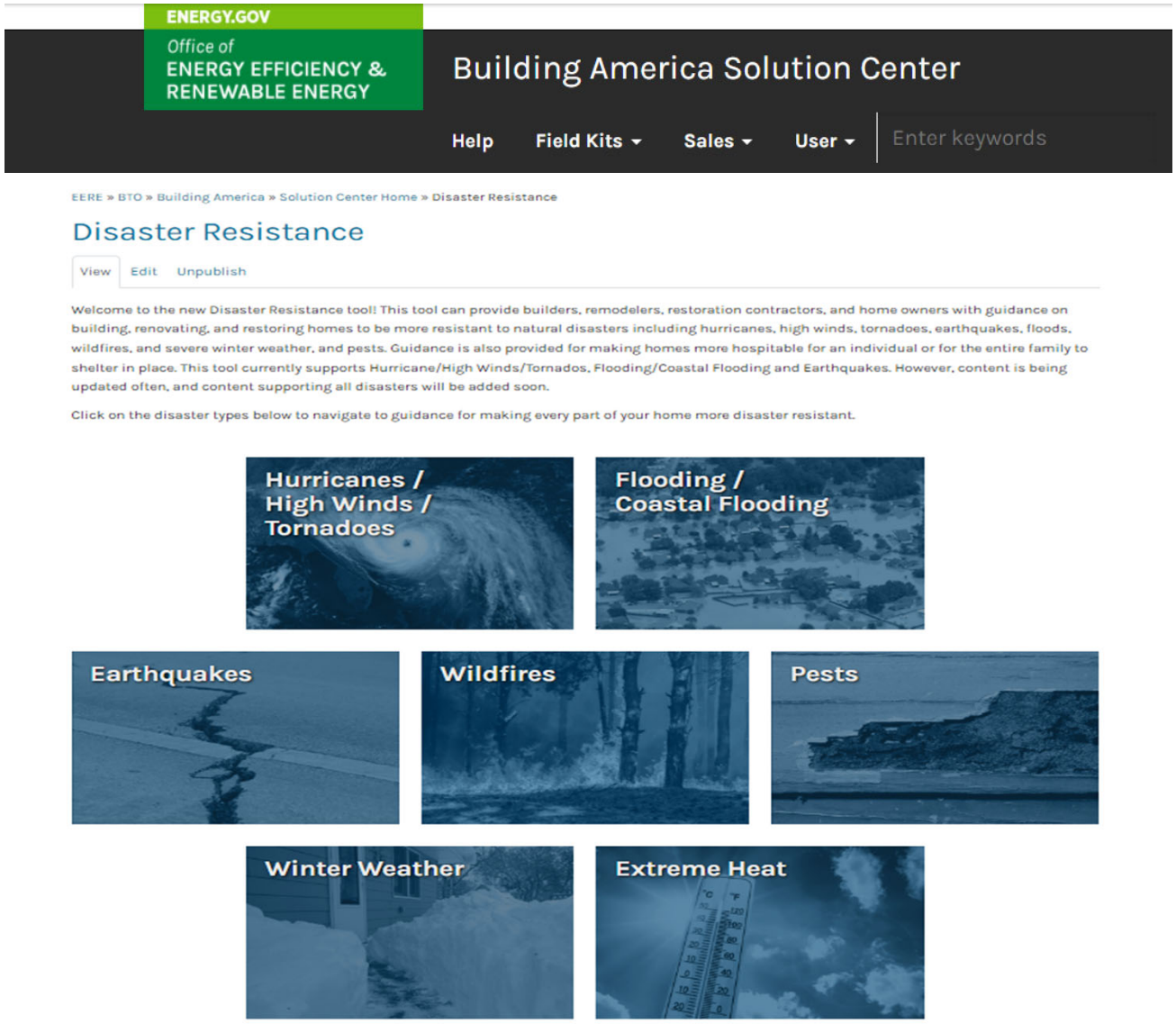

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Questions?

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