Building for Energy Efficiency and Disaster Resistance: Complementary Goals, Most of the Time

Presented at: 6th Residential Building Design & Construction Conference,
Pennsylvania Housing Research Center
May 12, 2022, Virtual

Edward Louie, PNNL
Terri Gilbride, PNNL
Chrissi Antonopoulos, PNNL

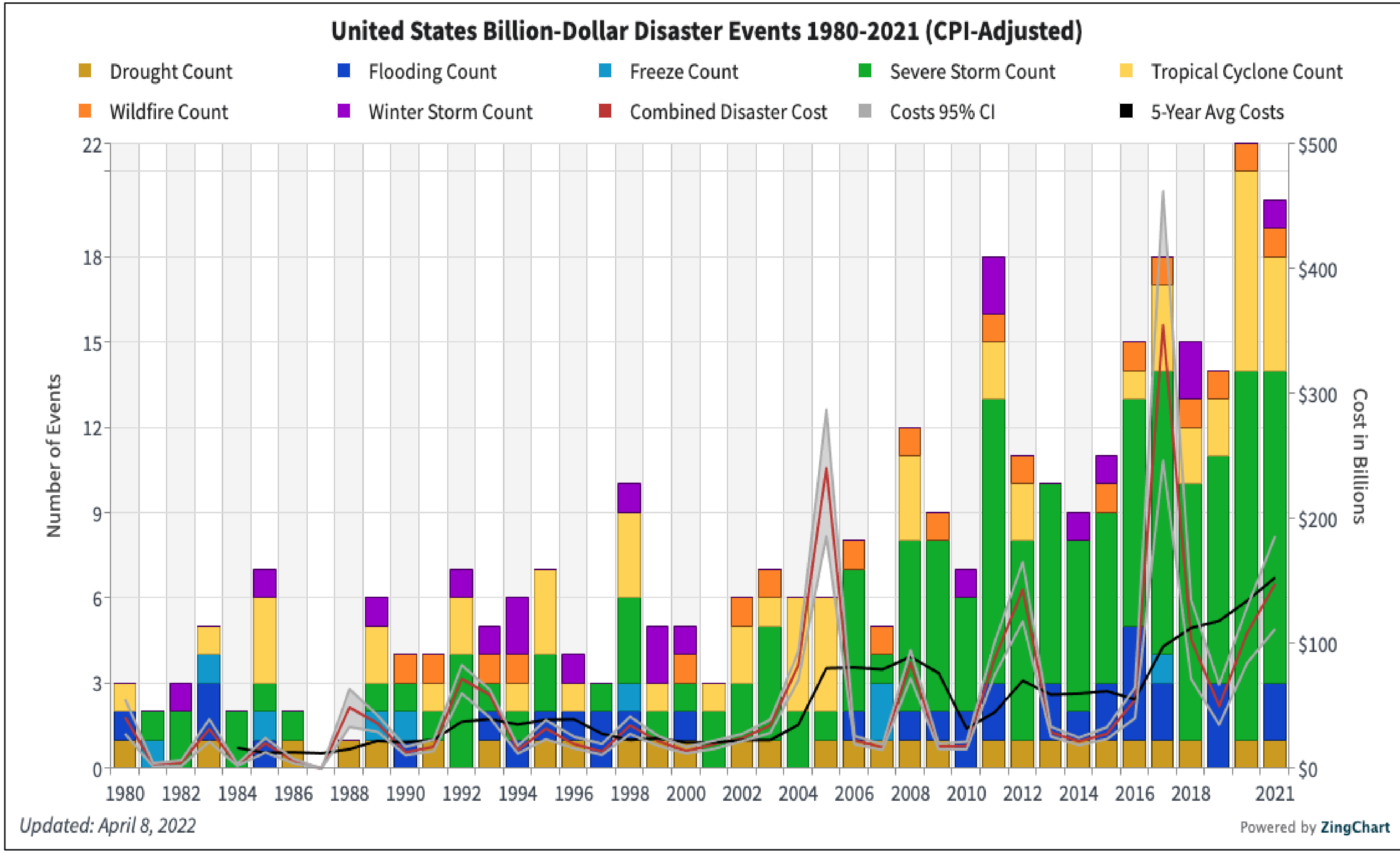
Pacific Northwest
NATIONAL LABORATORY

Presentation Outline

1. Intro – Importance of examining the nexus of energy efficiency and disaster resistance
2. Role of high-performance builders
3. Table – Energy efficiency and disaster resistance complements and conflicts
4. Solutions to conflicts
5. Intro to BASC Disaster Resistance Tool

Big Disaster Events on the Rise

- **22** billion-dollar disaster events in 2020
- **6 more** than previous record of 16 in 2017 and 2011
- **262 deaths**
- **$95 billion** in damages
- **$1.875 trillion** since 1980



Pacific Northwest
NATIONAL LABORATORY

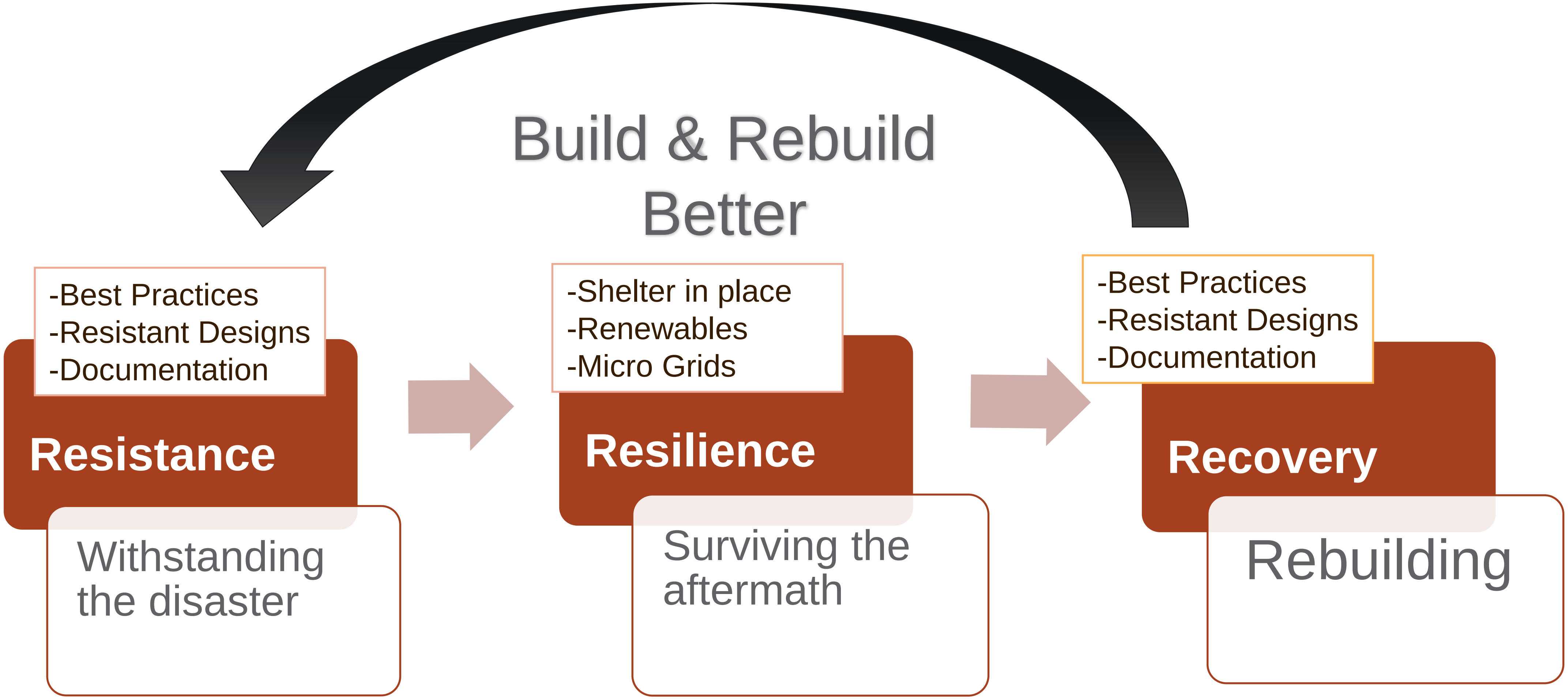
Source: NOAA

The High-Performance Value Proposition

- High-performance builders are already building disaster-resistant homes.
- Minor adjustments to materials and approaches in different climate zones can help ensure a more resilient housing stock.
- Builders experienced in their geographic locality understand the risks in their climate zone and the associated best practices for mitigating risks.

Pacific Northwest
NATIONAL LABORATORY

Builders play a fundamental role in housing resilience



EE homes are (mostly) disaster-resistant homes

Energy Efficiency → Disaster Resistance

ZERO ENERGY READY HOME
U.S. DEPARTMENT OF ENERGY

ENERGY STAR

EPA Indoor airPLUS
QUALIFIED HOME

WaterSense
Meets EPA Criteria

Energy Efficiency - Disaster Resistance Nexus

Disaster Risk	Complement	Potential Conflict
Wildfires	Unvented Attics	Vented Attics
	Noncombustible Materials	Flammable Insulation
	ERV or Supply with Filtration	Back-Vented Walls
		Mechanical Ventilation (exhaust only)
High Winds/Impact (hurricanes, tornadoes)	Sealed Seams	Back-Vented Walls
	Masonry Walls	Vented Attics
	Operable Shutters	Overhangs
	Larsen Truss Walls using I-Joist	Advanced Framing (1 top plate 2-stud corners)
Earthquakes	Wood-Framed Walls	Masonry Walls
Floods	Raised Homes	Unvented Crawl Space
	Masonry Walls	Insulated Slab
	Rigid foam/spray foam	
Severe Winter Weather	Vented Attics	Unvented Attics Heat Pumps
Extreme Heat	Air Sealing	HVAC in vented attic?
	Efficient HVAC (Heat Pumps)	
	Drought-Tolerant Landscaping & Shading	
Pests	Mineral Wool	Foam Insulation
Post-Event Occupancy	High-Performance Enclosure	Solar without batteries
	Shading/High Insulation/Operable Windows	
	Solar Electric/Thermal; Batteries	
	Grid-Integrated Efficient Buildings	

Wildfires & Envelope

Disaster Risk	Complement	Potential Conflict
Wildfires	Unvented Attics Noncombustible Materials	Vented Attics Flammable Insulation Back-Vented Walls

Vented Attics & Back Vented Walls

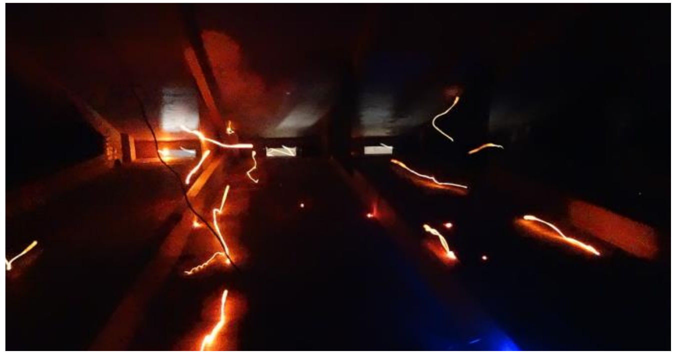
Good for energy efficiency and durability.

- Problem, venting can allow hot embers to enter and contact combustible materials
- Solution, fine screened vents with intumescent material

Rigid Foam Exterior CI

Good for energy efficiency and durability.

- Problem, EPS, XPS, and ISO rigid foams can melt, emit noxious fumes, and/or burn.
- Solution, use mineral wool insulation instead or protect rigid foam with gypsum or ignition barrier.



Long exposure images showing wildfire embers entering a vented attic through the soffit and gable vent. (Insurance for Business and Home Safety 2017).

Example comparison between a vent with an intumescent coating and one that does not (Ember Defense LLC, n.d.) Dr. Energy Saver. (2013). Fire Testing Insulation Materials. YouTube Video.

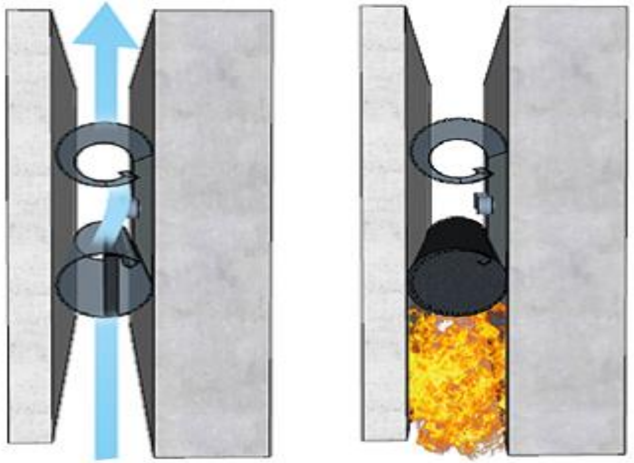


Illustration of how an intumescent fire block in the rainscreen layer behaves normally and during a fire (Odice, n.d.)

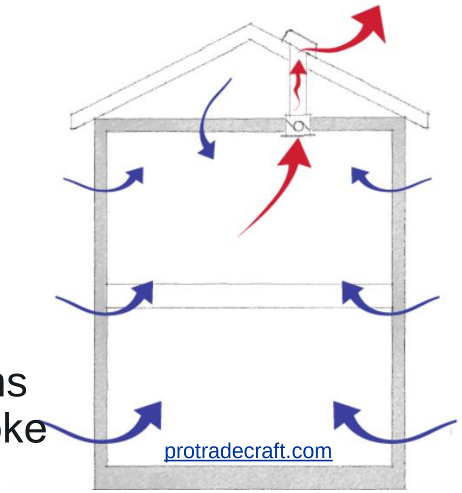
Wildfires & Mechanical Ventilation

Disaster Risk	Complement	Potential Conflict
Mechanical Ventilation	ERV or Supply with Filtration	Exhaust

Mechanical Ventilation

Built tight and ventilate right

- Problem: MV can make IAQ worse if outdoor air is polluted
- Solutions:
  - Disable MV systems that don't have good filtration (exhaust only and supply only systems that don't have good filters) when wildfire smoke is thick outside.
  - Filter indoor air using high MERV filters.
  - Install MV systems with good filtration.



protradecraft.com

IQAir AirVisual Pro

Allison A. Bailes III. 2020

Fox 12 News

High Winds/Impact (hurricanes, tornadoes)

Disaster Risk	Complement	Potential Conflict
High Winds/Impact (hurricanes, tornadoes)	Sealed Seams	Back-Vented Walls
	Masonry Walls	Vented Attics
	Operable Shutters	Overhangs
	Larsen Truss Walls using I-Joist	Advance Framing (1 top plate 2-stud corners)

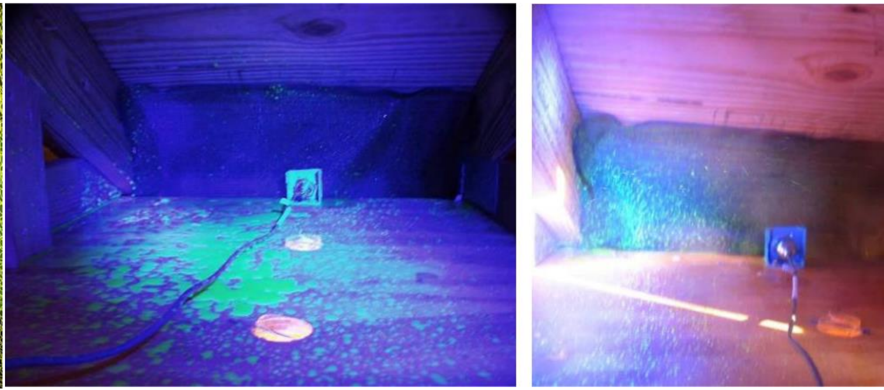
Back-Vented Walls
- Problem: Furring strips decrease the amount of continuous siding support, increasing the chance of breakage from impact by wind-driven debris.
- Solution: Use continuous rainscreen mesh/mats and flexible siding like engineered wood siding that dents before breaking

Vented Attics
- Problem: Wind driven rain, wind-washed insulation
- Solution: Unvented attic. Vented roof over unvented attic. Vents designed to resist rainwater entry.

Overhangs
- Problem: In high-wind zones, wind uplift can pull apart the overhang, esp. ladder framed gable overhangs.
- Solution: Brace overhangs with proper fasteners and metal connectors

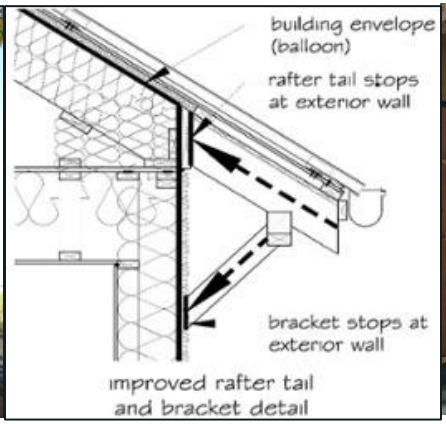
Advanced Framing
- Problem: out-of-plane buckling when using single top-plates, two-stud corners, 2x4 24-inch on-center, around windows and patio doors
- Solution: Use 2x6 or 2x8 studs, install Larsen trusses (or use double top-plates)

benjaminobdyke.com



Wind Driven Rain Visualization with Fluorescent Tracer Dye (Masters 2006)

Example Gable Overhang Bracing Using Gallow Brackets (Mahan 2014)



Example of an applied eave that attaches to the wall (Bailes, 2011)

Larsen trusses can improve out-of-plane buckling (Ecohome 2019)

High Winds/Impact (hurricanes, tornadoes)

Pacific Northwest
NATIONAL LABORATORY

Disaster Risk	Complement	Potential Conflict
High Winds/Impact (hurricanes, tornadoes)	Sealed Seams	Back-Vented Walls
	Masonry Walls	Vented Attics
	Operable Shutters	Overhangs
	Larsen Truss Walls using I-Joist	Advance Framing (1 top plate 2-stud corners)

Advanced Framing

- Problem: Getting enough uplift and overturning capacity with advanced framing.
- Solution: Use structural screws fit for purpose with aligned single top plate
- Solution: Minimize overturning force resistance required by building square homes and not installing stone/brick veneer walls on 2nd floor

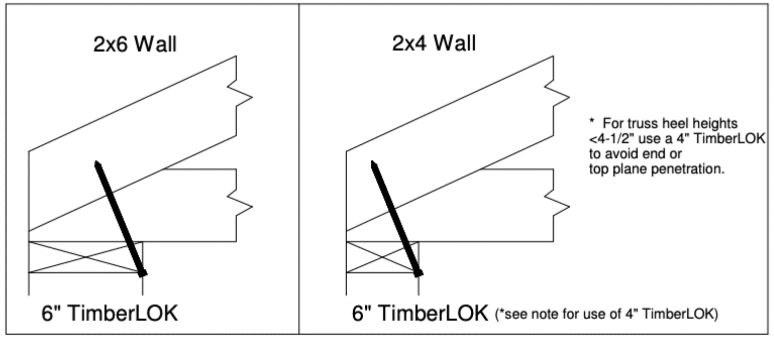
AUGUST 1, 2016	TimberLOK SINGLE TOP PLATE TO TRUSS CONNECTION	MII - TimberLOK (SINGLE TOP PLATE)

MiTek USA, Inc. Page 1 of 1

MiTek USA, Inc.
ENGINEERED BY TRENCO
A MiTek Affiliate

mitek-us.com

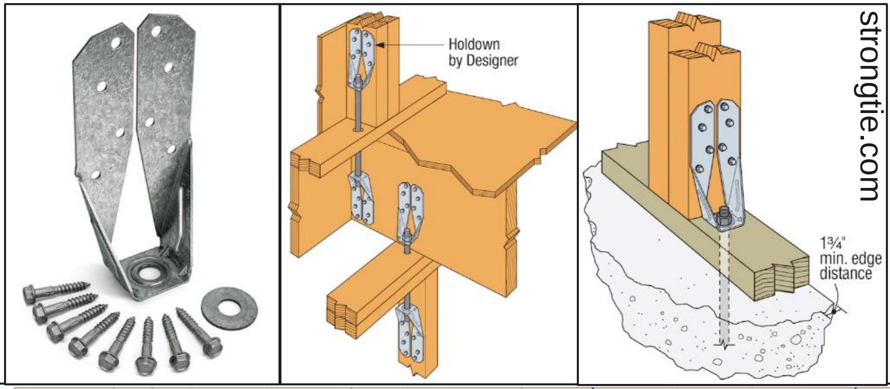
NOTES:
1. SELECT A TimberLOK SCREW WITH A LENGTH SUFFICIENT TO FULLY EMBED THE 2" THREADED PORTION OF THE SCREW INTO THE TRUSS OR RAFTER.
2. WHERE THE TRUSS OR RAFTER IS LOCATED DIRECTLY OVER A WALL STUD, INSERT THE SCREW AT THE JOINT BETWEEN THE INSIDE TOP EDGE OF THE STUD AND THE INSIDE BOTTOM EDGE OF THE TOP PLATE AT A 25 DEGREE ANGLE (+/- 5 DEGREE) AND INTO THE CENTER OF THE TRUSS.
3. WHERE THE CENTERLINE OF THE TRUSS OR RAFTER IS NOT LOCATED DIRECTLY OVER THE STUD, INSTALL THE SCREW VERTICALLY UP THROUGH THE TOP PLATE AND INTO THE TRUSS, RAFTER.
4. SCREW MUST BE DRIVEN INTO THE CENTER OF THE 1-1/2" TRUSS CHORD EDGE (+/- 1/4") WITH THE THREADS FULLY ENGAGED IN THE TRUSS CHORDS (BOTTOM CHORD, TOP CHORD OR BOTH ARE ACCEPTABLE).
5. BRING THE SCREW HEAD FLUSH WITH THE WOOD SURFACE.
6. MULTIPLE PLY TRUSSES SHALL HAVE ONLY ONE SCREW. (DO NOT USE ONE SCREW PER PLY)
7. LOADS ACTING IN TWO DIRECTIONS SIMULTANEOUSLY MUST BE EVALUATED AS FOLLOWS: DESIGN SHEAR/ ALLOWABLE SHEAR + DESIGN UPLIFT/ ALLOWABLE UPLIFT <=1.0
8. USE THE LOWER OF THE TWO VALUES IF MIXED SPECIES ARE INVOLVED.



TimberLOK Design Loads for Truss to Top Plate Connections (lb.)

Wood Species	SPF/HF			Douglas Fir			Southern Pine		
		Lateral/Shear			Lateral/Shear			Lateral/Shear	
Load Type	Uplift	Parallel to Wall	Perpendicular to Wall	Uplift	Parallel to Wall	Perpendicular to Wall	Uplift	Parallel to Wall	Perpendicular to Wall
Allowable Load	420	320	370	540	385	425	620	410	450

A STANDARD LOAD DURATION FACTOR OF 1.6 HAS BEEN APPLIED TO THESE VALUES PER NDS TABLE 2.3.2



Model No.	Ga.	Dimensions (in.) W	H	B	CL	SO	Fasteners (in.) Anchor Bolt Dia. (in.)	Wood Fasteners	Minimum Wood Member Size (in.)	Allowable Tension Loads (160) DF/SP	SPF/HF	Deflection at Allowable Load (in.)	Code Ref.
DTT1Z	14	1½	7⅛	1 7/16	¾	3/16	⅜	(6) #9 x 1½" SD	1½ x 5½	840	840	0.17	IBC, FL, LA
								(6) 0.148 x 1½		910	640	0.167	
								(8) 0.148 x 1½		910	850	0.167	
DTT2Z	14	3¼	6 15/16	1⅝	13/16	3/16	½	(8) ¼ x 1½ SDS	1½ x 3½	1,825	1,800	0.105	
								(8) ¼ x 1½ SDS	3 x 3½	2,145	1,835	0.128	
DTT2Z-SDS2.5								(8) ¼ x 2½ SDS	3 x 3½	2,145	2,105	0.128	
HDU2-SDS2.5	14	3	8 11/16	3¼	1 5/16	1⅜	⅝	(6) ¼ x 2½ SDS	3 x 3½	3,075	2,215	0.088	
HDU4-SDS2.5	14	3	10 15/16	3¼	1 5/16	1⅜	⅝	(10) ¼ x 2½ SDS	3 x 3½	4,565	3,285	0.114	
HDU5-SDS2.5	14	3	13 3/16	3¼	1 5/16	1⅜	⅝	(14) ¼ x 2½ SDS	3 x 3½	5,645	4,340	0.115	
HDU8-SDS2.5	10	3	16⅝	3½	1⅜	1½	⅞	(20) ¼ x 2½ SDS	3 x 3½	6,765	5,820	0.11	
									3½ x 3½	6,970	5,995	0.116	
									3½ x 4½	7,870	6,580	0.113	
HDU11-SDS2.5	10	3	22¼	3½	1⅜	1½	1	(30) ¼ x 2½ SDS	3½ x 5½	9,535	8,030	0.137	
									3½ x 7¼	11,175	9,610	0.137	
HDU14-SDS2.5	7	3	25 11/16	3½	1 9/16	1 9/16	1	(36) ¼ x 2½ SDS	3½ x 5½	10,770	9,260	0.122	—
									3½ x 7¼	14,390	12,375	0.177	IBC, FL, LA
									5½ x 5½	14,445	12,425	0.172	

Earthquakes

Disaster Risk	Complement	Potential Conflict
Earthquakes	Wood Frame Walls	Masonry Walls

Masonry Walls

- Problem – veneer brick or stone falls off walls.
- Solution:

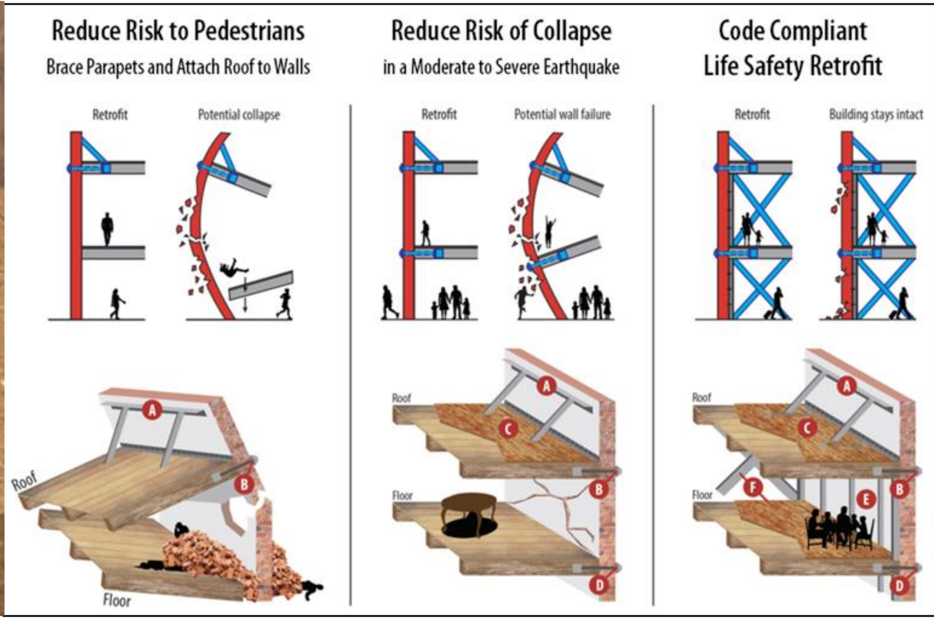
  New Construction: Install brick or stone veneer with adequate brick ties. Follow or exceed code for wall strength

  Retrofit: – under-reinforced veneer on weak walls – to fix, replace veneer with new lighter weight siding, like vinyl or fiber cement.

  Unreinforced structural brick or masonry – to fix, install steel braces and screw into brick or masonry wall.

Earthquake Fragility of Masonry Veneers (Khosravikia et al. 2020)

Retrofit ties for brick veneer (Hohmann & Barnard 2018)



Example of ways existing unreinforced masonry structures can be reinforced to prevent loss of life during an earthquake. (City of Portland, n.d.)

Floods

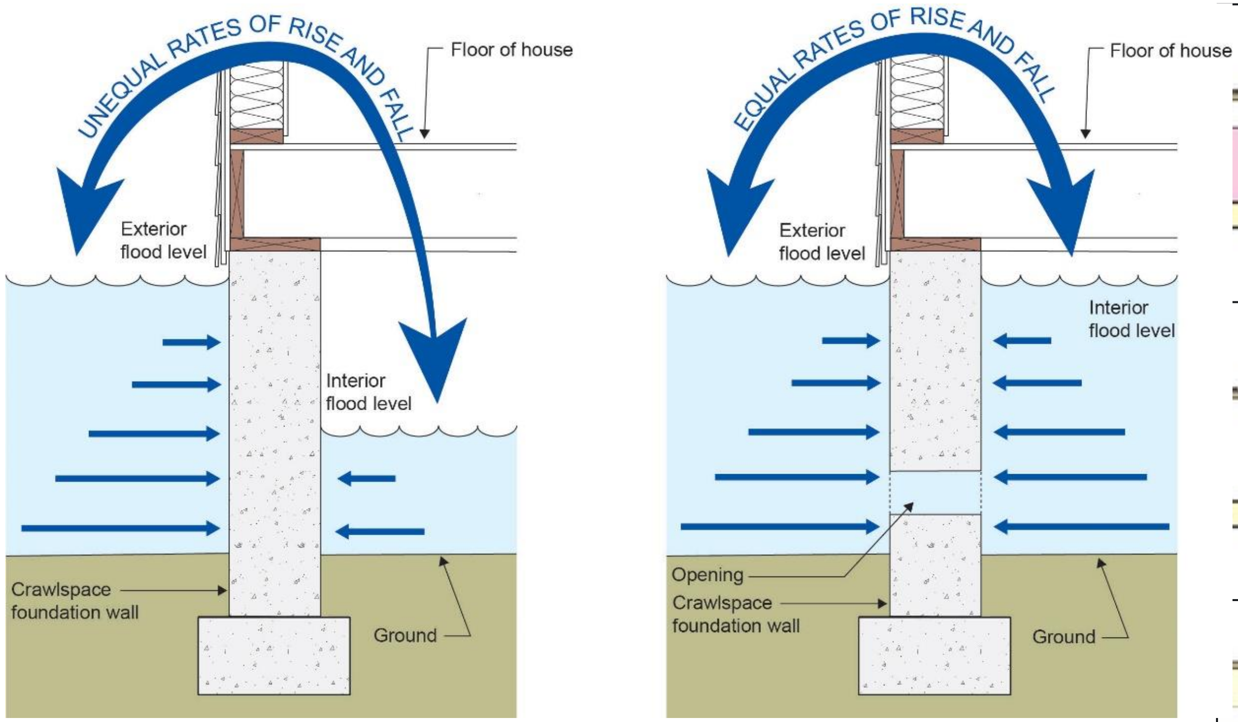
Disaster Risk	Complement	Potential Conflict
Floods	Raised Homes	Unvented Crawlspace
	Masonry Walls	
	Rigid foam/spray foam	

Unvented Crawlspace

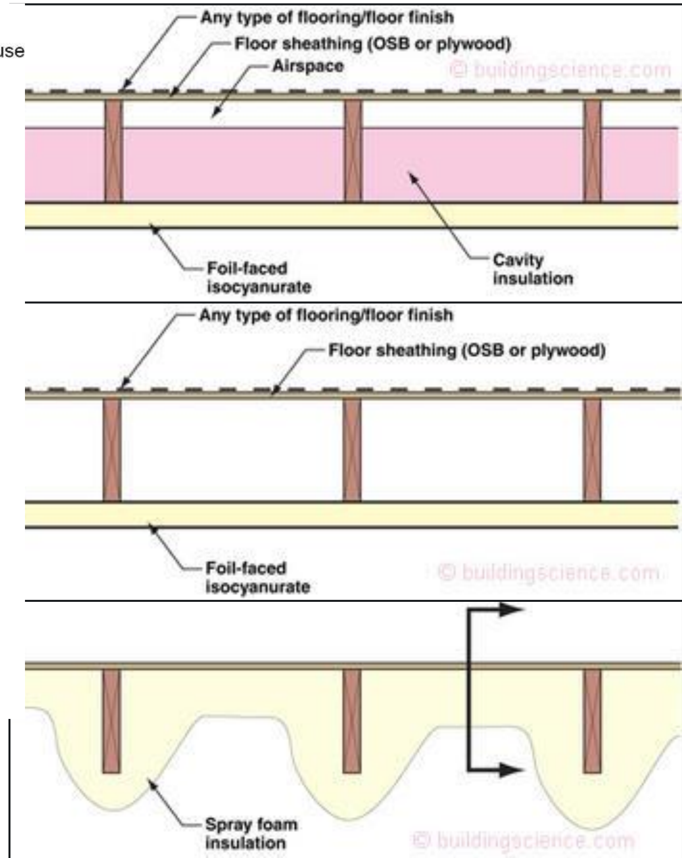
- Problem: Flood water can overwhelm lateral resistance of foundation wall.
- Solution: Cut holes in existing foundation wall to allow floor water to enter and exit the crawlspace. Install insulation and air sealing at the floor joists.

Crawlspace Designed for Floods

(Lstiburek 2022)



Three ways to insulate and air seal at the floor joist plane (Lstiburek, 2010)



Severe Winter Weather

Disaster Risk	Complement	Potential Conflict
Severe Winter Weather	Vented Attics	Unvented Attics

Unvented Attics

Problem: ice damming! No amount of insulation will help.

Solution: New - Construct vented attics or add a vented over-roof to an unvented attic.

Retrofit – For vented attics with inadequate insulation at eaves and limited soffit or gable venting, install closed-cell spray foam over the top plates and along the underside of the roof deck above the top plates to maximize the R-value at the eaves.

Coldham & Hartman Architects Published in GBA 2010

Extreme Heat

Disaster Risk	Complement	Potential Conflict
Extreme Heat	Air Sealing	HVAC in vented attic
	Efficient HVAC (Heat Pumps)	
	Drought-Tolerant Landscaping & Shading	

HVAC in Vented Attic

Problem: HVAC equipment is exposed to extreme temperatures, greatly reduces cooling capacity, and risk of condensation and mold in the ducts.

Solution:

New Construction: Don’t put HVAC in the attic, put ducts inside conditioned space.

Retrofit: Spray foam underside of roof deck to convert the unvented attic to conditioned space, or move all ducts inside conditioned space, or decommission the ducted system by sealing off the vents and install mini-split heat pumps.

4 Ways to do Ducts Inside (Roberts and Winkler 2010)

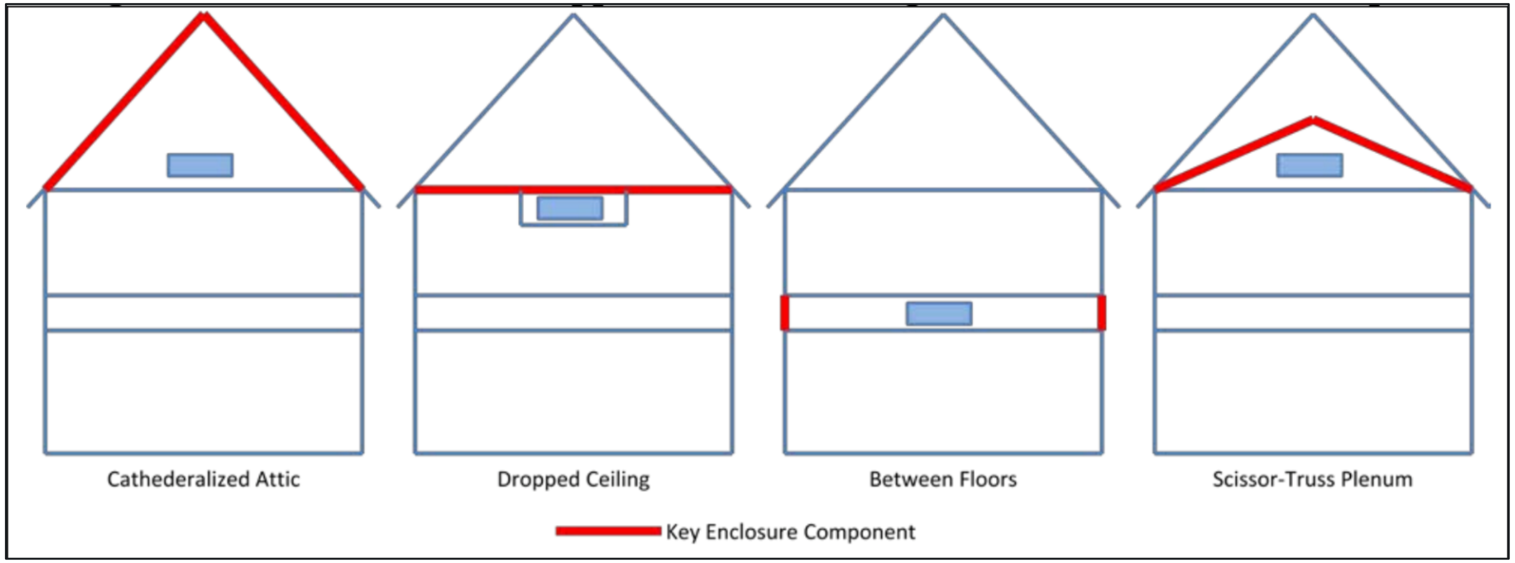


Figure 5. Reduction in Cooling Electricity Usage for Various Efficiency Upgrades

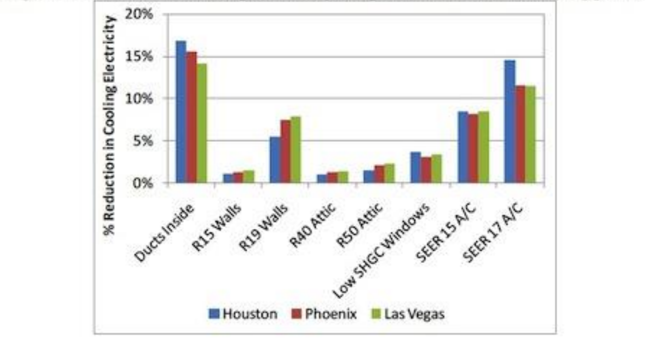
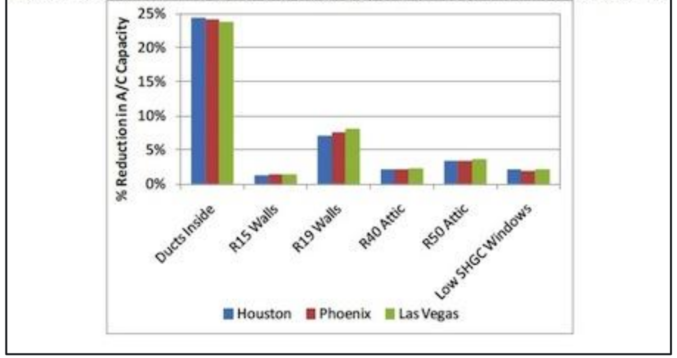


Figure 4. Reduction in Required Cooling Capacity for Various Efficiency Upgrades



Pests

Disaster Risk	Complement	Potential Conflict
Pests	Mineral Wool	Foam Insulation

Foam Insulation

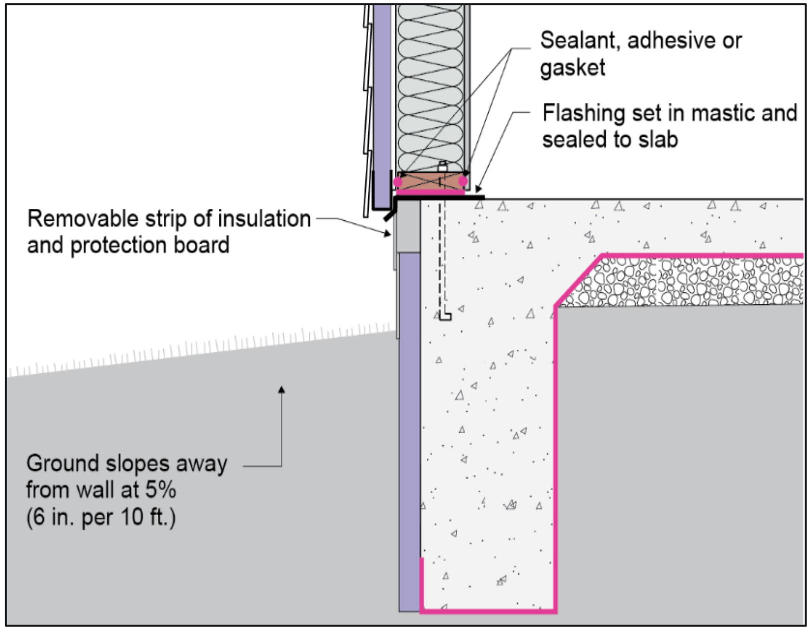
Problem: Termites will burrow thru foam to access wood

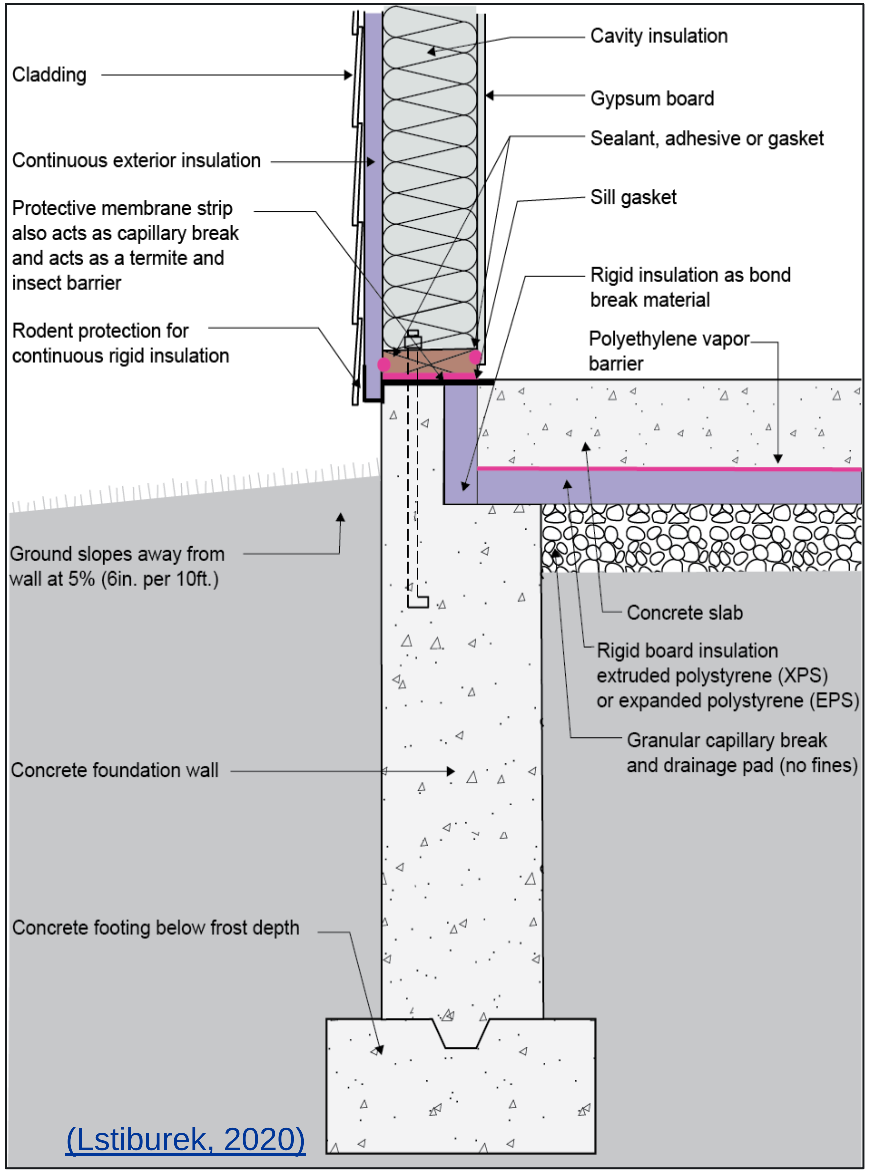
Solution: Cover and protect foam and/or sill plates with metal flashing.

Leave a 3-inch horizontal pest inspection strip at top of interior foam insulated basement and crawlspace walls.

Avoid foundation designs that require foam on the outside in contact with soil.

Example of foam board insulation that termites have tunneled through (Campbell Law, P.C. 2013).





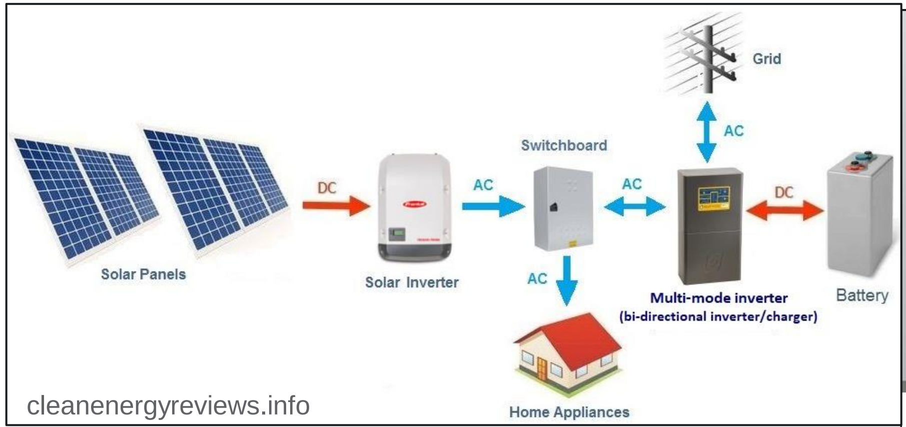
(Lstiburek, 2020)

Post-Event Occupancy

Disaster Risk	Complement	Potential Conflict
Post-Event Occupancy	Shading/High Insulation/Operable Windows Solar Electric/Thermal; Batteries Grid-Integrated Efficient Buildings	Solar without Batteries (or PV systems with batteries but not setup for backup power)

Rooftop Solar System
Problem: Standard PV don't work during a blackout to prevent dangerous back feeding the utility lines which could injure utility workers

Solutions:
- Standalone back power systems not connected to the grid
- PV inverter systems with automatic transfer switches to go into island mode. Bi-modal and multi-modal inverters have this automatic transfer built-in.
- Energy efficient appliances can run longer on battery and require smaller inverters



cleanenergyreviews.info

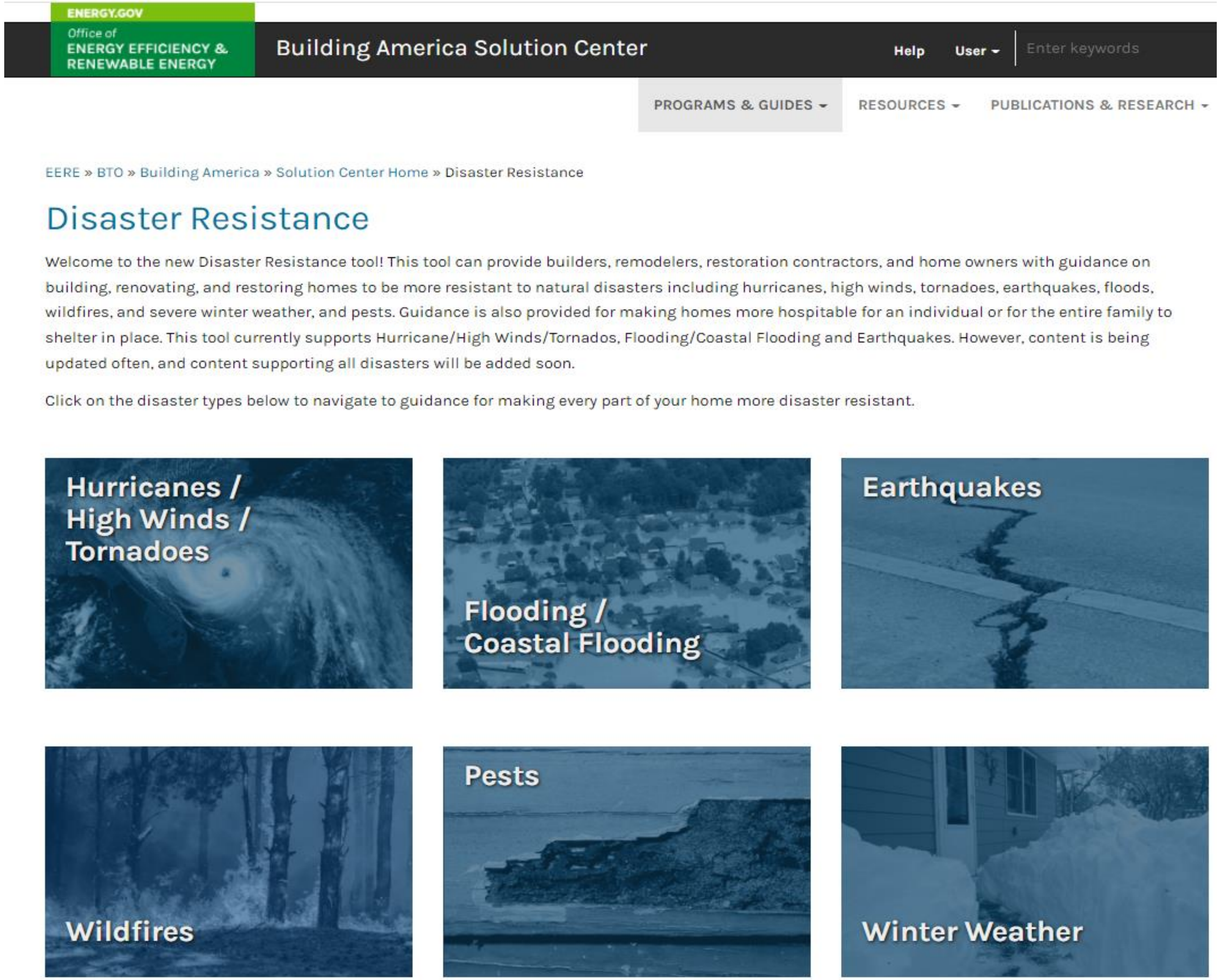

bluettipower.com


jackery.com


solarpowerworldonline.com

Pacific Northwest
NATIONAL LABORATORY

www.BASC.pnnl.gov/disaster-resistance



ENERGY.GOV
Office of
ENERGY EFFICIENCY & RENEWABLE ENERGY

Building America Solution Center

Help User Enter keywords

PROGRAMS & GUIDES RESOURCES PUBLICATIONS & RESEARCH

EERE » BTO » Building America » Solution Center Home » Disaster Resistance

Disaster Resistance

Welcome to the new Disaster Resistance tool! This tool can provide builders, remodelers, restoration contractors, and home owners with guidance on building, renovating, and restoring homes to be more resistant to natural disasters including hurricanes, high winds, tornadoes, earthquakes, floods, wildfires, and severe winter weather, and pests. Guidance is also provided for making homes more hospitable for an individual or for the entire family to shelter in place. This tool currently supports Hurricane/High Winds/Tornados, Flooding/Coastal Flooding and Earthquakes. However, content is being updated often, and content supporting all disasters will be added soon.

Click on the disaster types below to navigate to guidance for making every part of your home more disaster resistant.

Hurricanes / High Winds / Tornadoes

Flooding / Coastal Flooding

Earthquakes

Wildfires

Pests

Winter Weather

Pacific Northwest NATIONAL LABORATORY

Tool Organization

- Overview
- Design
- Roof
- Walls / Windows / Doors
- Building Attachments
- Foundation / Site
- Operations / Equipment

Walls

- **Moisture-, Impact-, Fire-, and Pest-Resistant Exterior Siding**
  Guide describing how to select the siding materials best suited to
  the home is likely to face within its lifetime.

- **Fire-Resistant Wall Assemblies**
  Guide describing wall assemblies and materials that are resistant
  wildfires.

Windows

- **Windows Have Impact-Rated Glass, Fire-Resistant Glass, or Pr**
  Guide describing how to strengthen or protect windows against wi
  debris during high-wind events including hurricanes and tornados

Doors

- **Exterior Doors Are Insulated, Impact Rated, and Fire Rated**
  Guide describing the use of doors that are impact rated or have pro
  hurricane and high wind zones.

Guides

Scope Tab

- 307 measure-specific guides.
- Provides a general scope for the measure.
- Specifies primary construction techniques.
- Highlights installation strategies.
- Can be used as a scope of work on a bid, contract, plan, or other construction documentation.

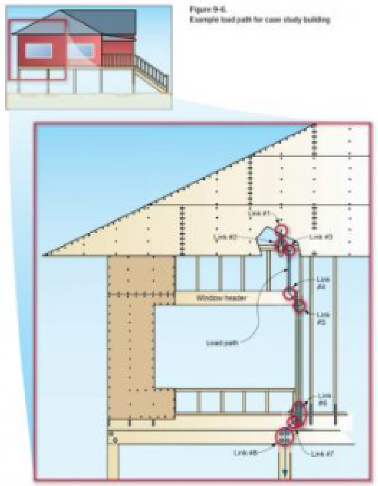
Continuous Load Path Provided with Connections from the Roof through the Wall to the Foundation

Print

Scope | Description | Success | Climate | Training | CAD | Compliance | Retrofit | More

Scope

Provide a strong and continuous load path from the roof to the foundation to avoid structural damage and to keep the building intact during hurricanes and other extreme storms.



Right - A continuous load path connects the roof and wall framing to the foundation.

Best practice steps for new construction:

- Determine the wind design velocity and if the house is in a hurricane-prone region.
- For hurricane-prone regions, a licensed structural engineer must determine the continuous load path connections.
- For areas where design wind speed is less than that of hurricane-prone regions, a prescriptive design approach may be used:
  - Ensure that roof framing, floor framing, wall framing, and foundations are constructed in accordance with all applicable building codes.
  - Specify and install a continuous load path, such that the building has positive connections from the roof to the foundation to resist and transmit wind uplift and lateral shear loads to the ground (see Description tab for above-code connectors):
    - Install roof sheathing-to-framing connections
    - Install roof-to-wall connections
    - Install wall above-to-below connections
    - Install wall-to-foundation connections
    - Install any chimney-to-roof member connections.

See the Compliance Tab for related codes and standards requirements, and criteria to meet national programs such as DOE's Zero Energy Ready Home program, ENERGY STAR Certified Homes, and EPA Indoor airPLUS.

Last Updated: 2020-09-24

"Building a resilient home that can deal with the consequences of climate change is becoming an important consideration when building any new home….as homebuilders, perhaps we are the ones who should proactively address these challenges."
--Thrive Home Builders

Pacific Northwest
NATIONAL LABORATORY

Thank you!

Join the conversation:

#2022RBDCC

Edward.Louie@PNNL.gov
Theresa.Gilbride@PNNL.gov
Chrissi.Antonopoulos@PNNL.gov