Resilient Design

Building for the Future Climate

Spaulding Rehab Hospital in Boston - photo: Perkins + Will

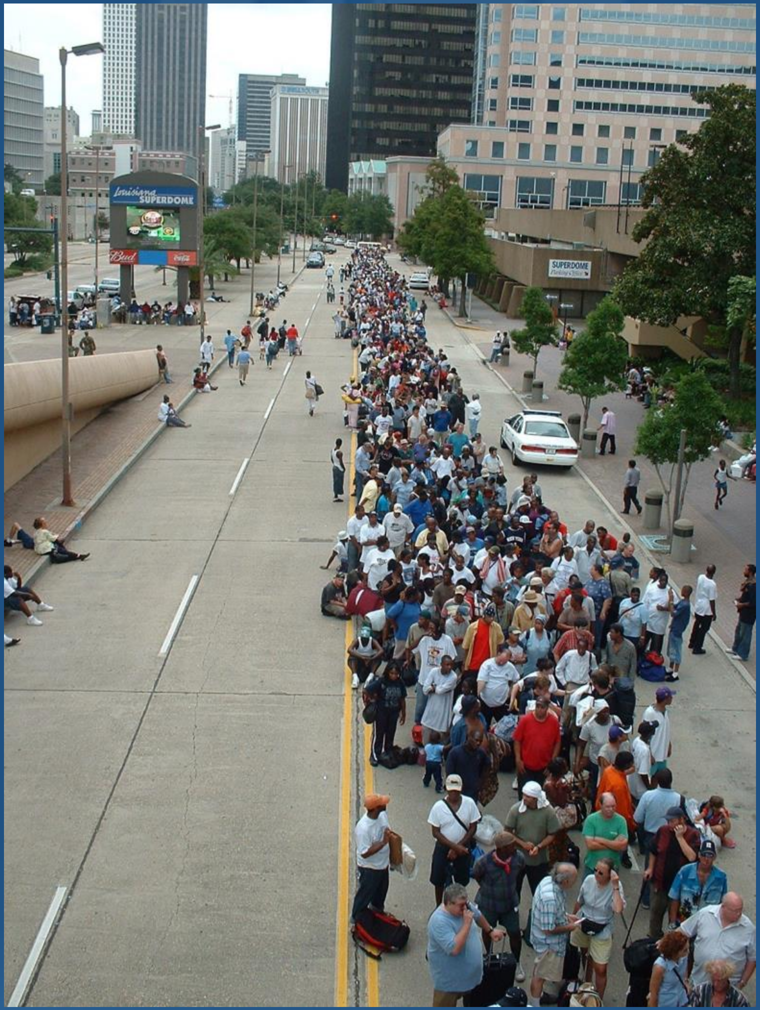
Local Solutions: Eastern Climate Preparedness Conference

May 1, 2018

Alex Wilson, President
Resilient Design Institute
Founder, BuildingGreen, Inc.

Waking up to the realities of climate change

- We need buildings and communities:
  - That are resistant to damage from storms
  - That will protect occupants from reasonably expected events
  - That will maintain livable conditions in the event of power outages, loss of fuel, or water shortages
- An issue both at the building scale and the community scale



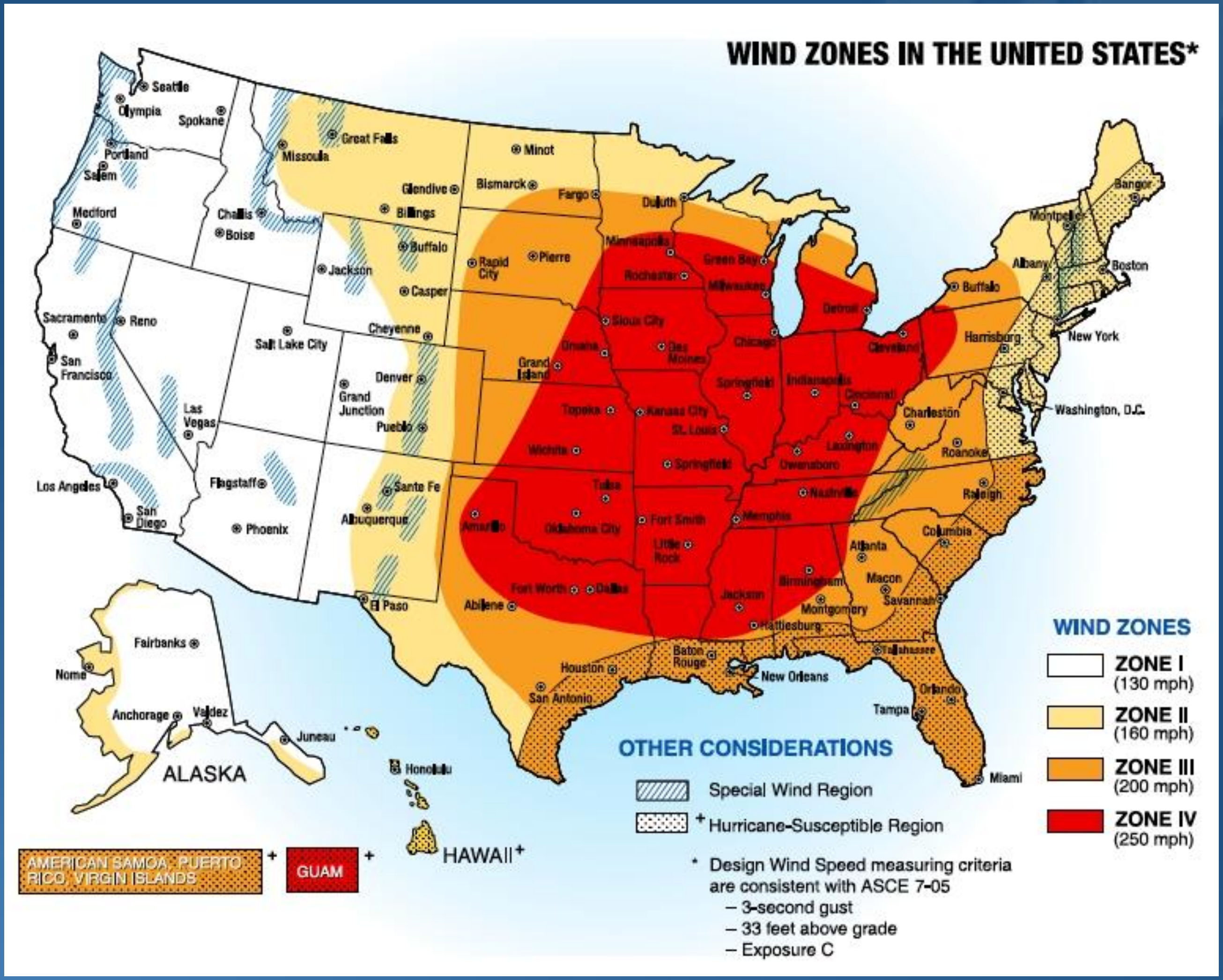
Residents evacuating to the Superdome during Hurricane Katrina. Photo: FEMA

A different motivation

- Safety vs. "doing the right thing"
- Speaks to self-interest
- Potential appeal to a broader political spectrum
- For me, the motivation is to gain more rapid buy-in and accomplish more
- Potential for incorporating measures into building codes

Net-zero-energy farmhouse in Vermont. Photo: Alex Wilson

Designing for Extreme Winds

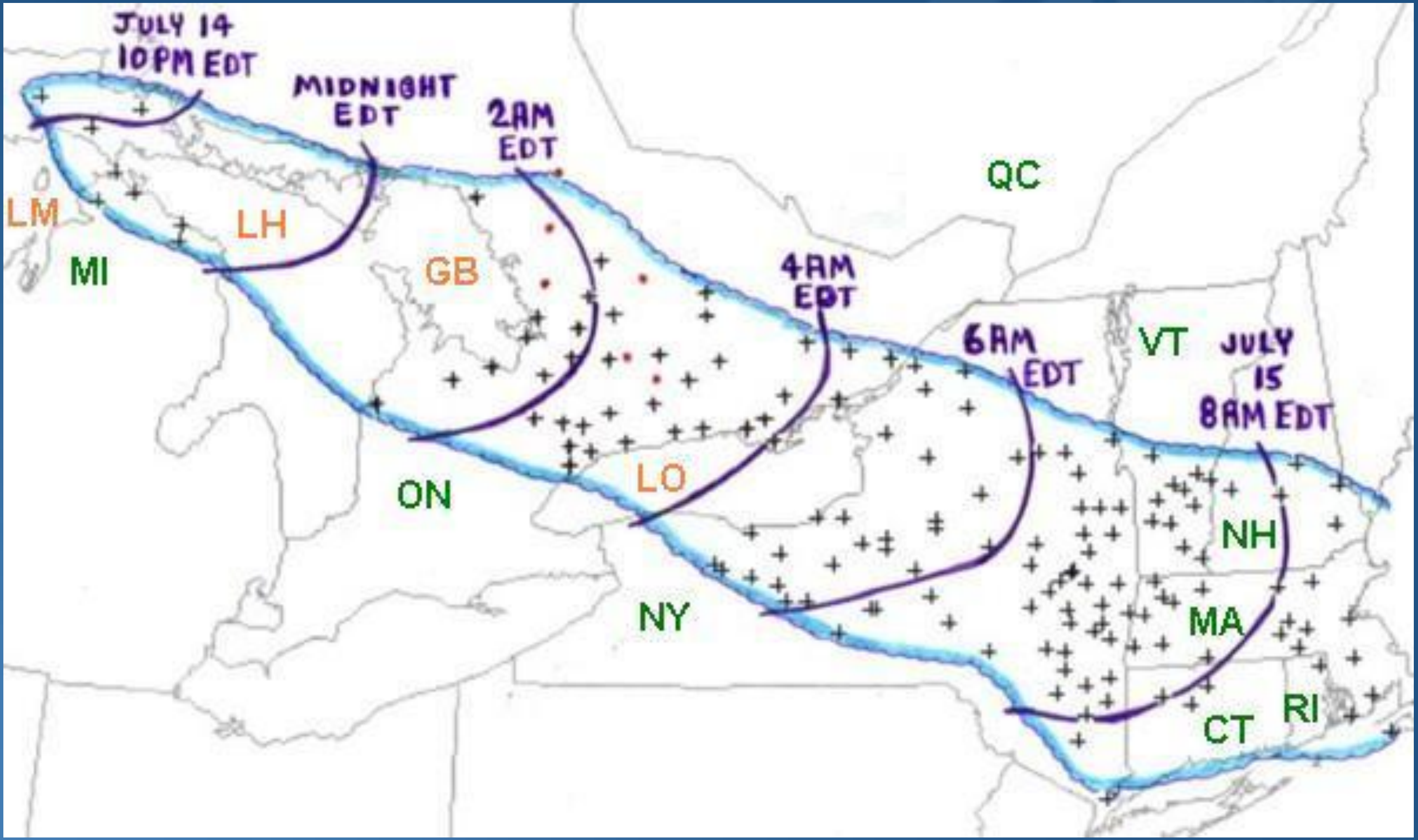


Wind zones in the U.S. from FEMA - Shelter from the Storm.

Designing for Extreme Winds

1995 derecho that hit the Adirondacks. Photo: Adirondack Almanac

Designing for Extreme Winds



Derecho storm track from July 15, 2005. Source: NOAA

Designing for Extreme Winds

Hurricane strapping and framing tie-down - photos: Simpson Strong-Tie

- Hurricane strapping and framing tie-down components
- More wind-resistant geometries: i.e., hip roofs
- High-strength roof sheathing
- Exterior shutters
- Resilient building systems, such as ICFs
- Adherence to Fortified Commercial: Hurricane or Fortified Commercial: High Wind & Hail
- Adherence to ASCE/SEI 7-10 – Min. Design Loads for Bldgs. & Other Structures

Designing for Extreme Winds

Simpson Strong-Tie hurricane straps in South Padre Island, Texas condo – photo: Rob Dickehuth

Designing for Tornados – Not only a concern in "Tornado Alley"

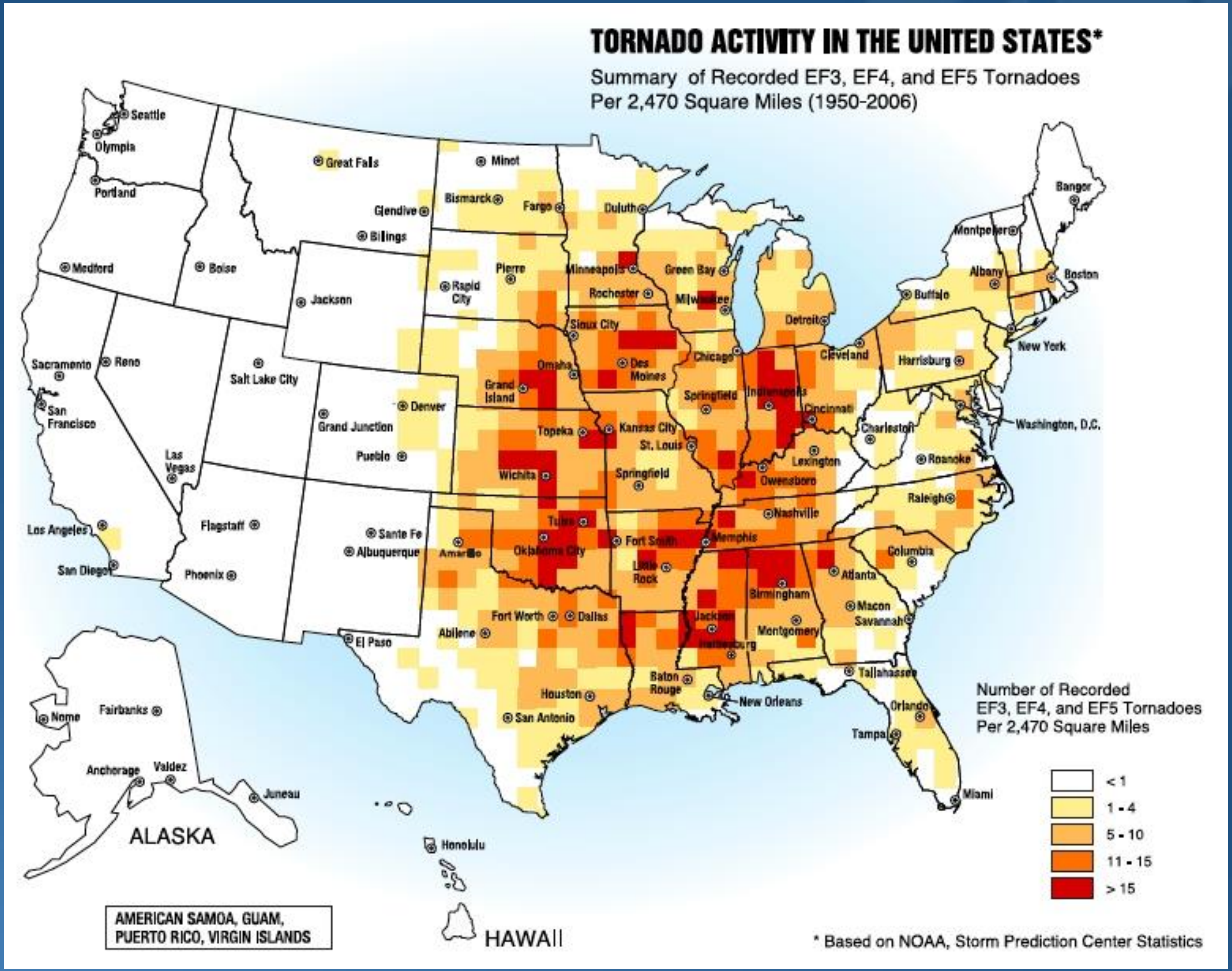
Assumption College damage from June 1953 Worcester F5 tornado; 94 killed, 1,288 injured, 15,000 left homeless. Photo: AP

Designing for tornados

Safe room being built in Sioux City, Iowa. Photo: Dave Gatley, FEMA

- Designing building to withstand tornados is not realistic
- Safe rooms: modular or site-built
- Typically concrete or reinforced masonry
- Anchored to bsmt. or garage slab
- Hurricane-rated door
- Outfitted with hand-crank radio and other emergency supplies

Designing for Tornados



NOAA tornado data – 1950 - 2006

Safe rooms – lots of options

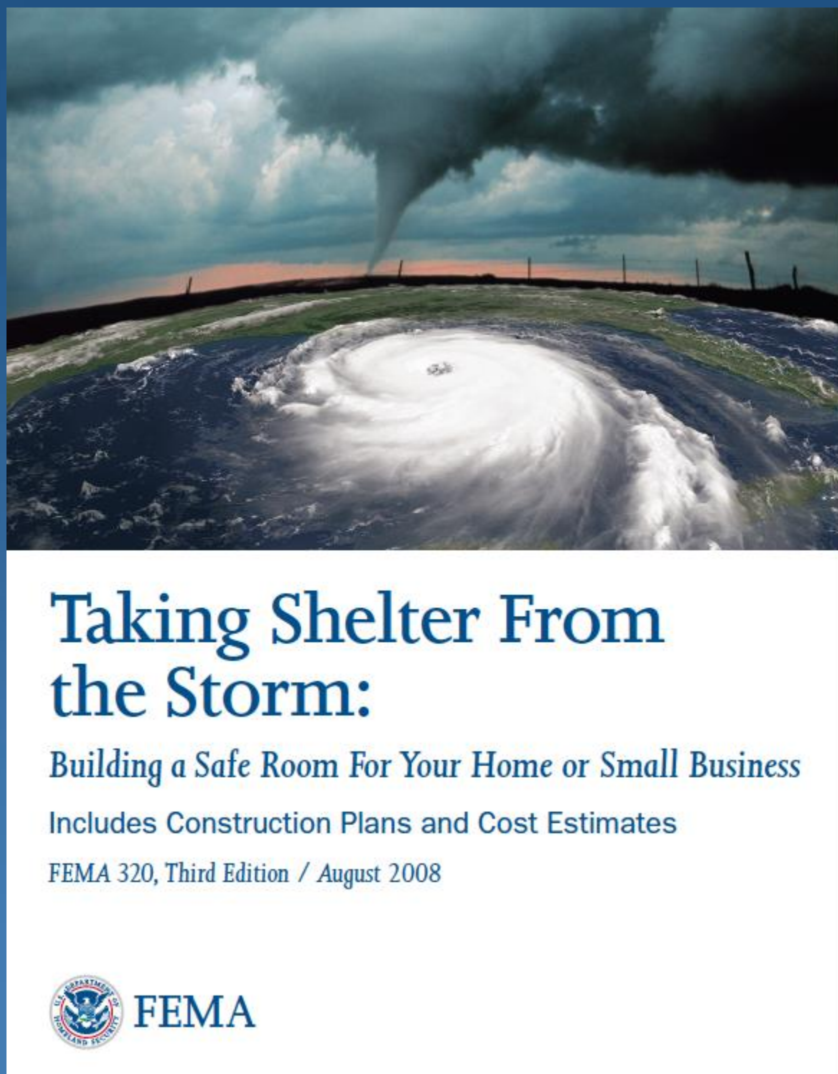
FamilySafe steel storm shelter under stairs

Secureall steel storm shelter

Safe rooms – they really work

Above-ground steel storm shelter after tornado - photo: FamilySafe Storm Shelters

Tornado safe rooms



- Adherence to Fortified Commercial: High Wind & Hail Standard
- Design of safe rooms using FEMA guidance:
  - P-320 (home and small business),
  - P-361 (community and residential buildings)
  - P-431 (refuge areas in buildings)
- Dozens of manufacturers of pre-fabricated safe rooms

Design for flooding

- Storm surge in coastal areas
- Tidal (clear-day) flooding due to sea level rise
- Inland riverine flooding from intense storms and spring runoff

Flat Street, Brattleboro, Vermont, Sept, 2011. Photo: Charlie Boswell

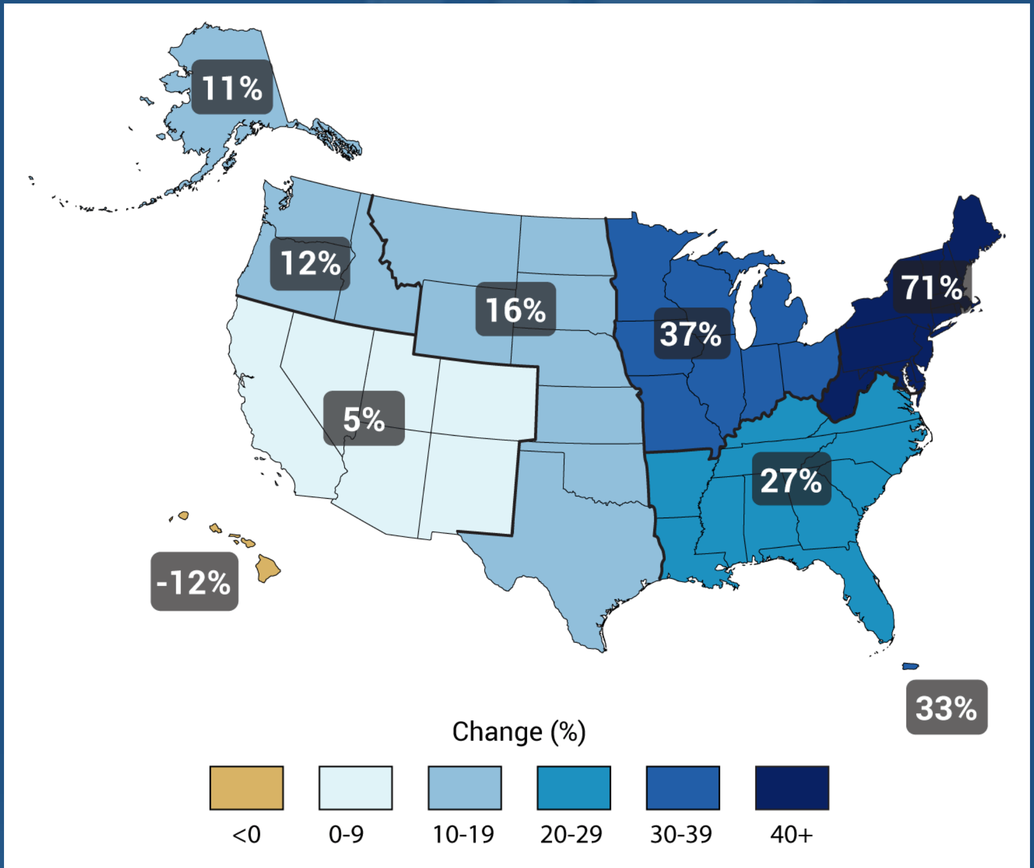
Surviving floods

New England Youth Theater, Brattleboro.
Photo: Jerry Stockman

New England Youth Theater, Brattleboro.
Photo: Jerry Stockman

Flooding

- 71% increase in intense storms in the Northeast from 1958 – 2012
- Similar trend in other regions—though not as extreme
- Even in areas where there may be less total rainfall, it is coming in more intense storms
- Causes river valley as well as coastal flooding

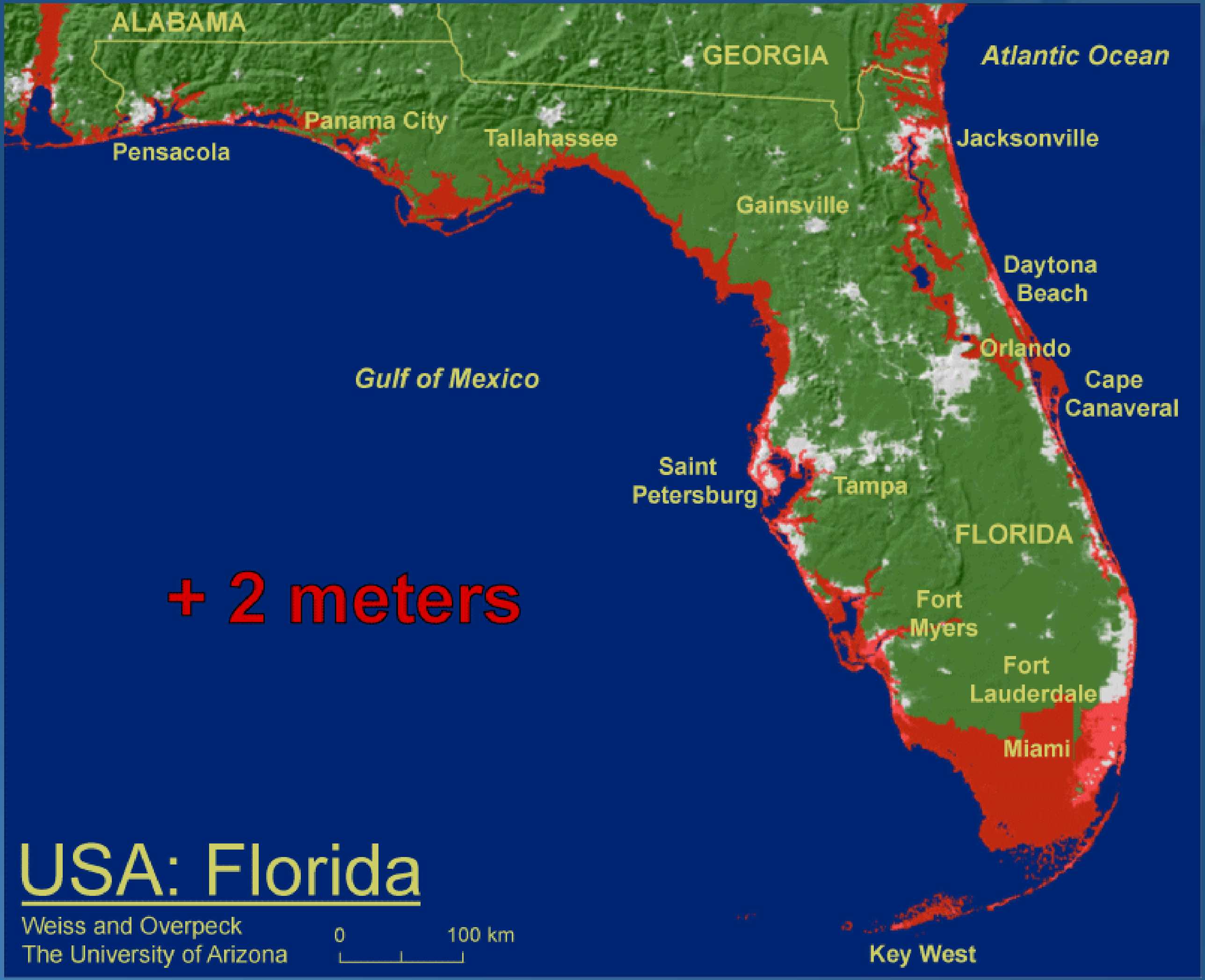


Percent increase in very heavy precipitation 1958-2012 (defined as the heaviest 1% of all events). Source: 2014 Nat'l Climate Assessment

Sea level rise

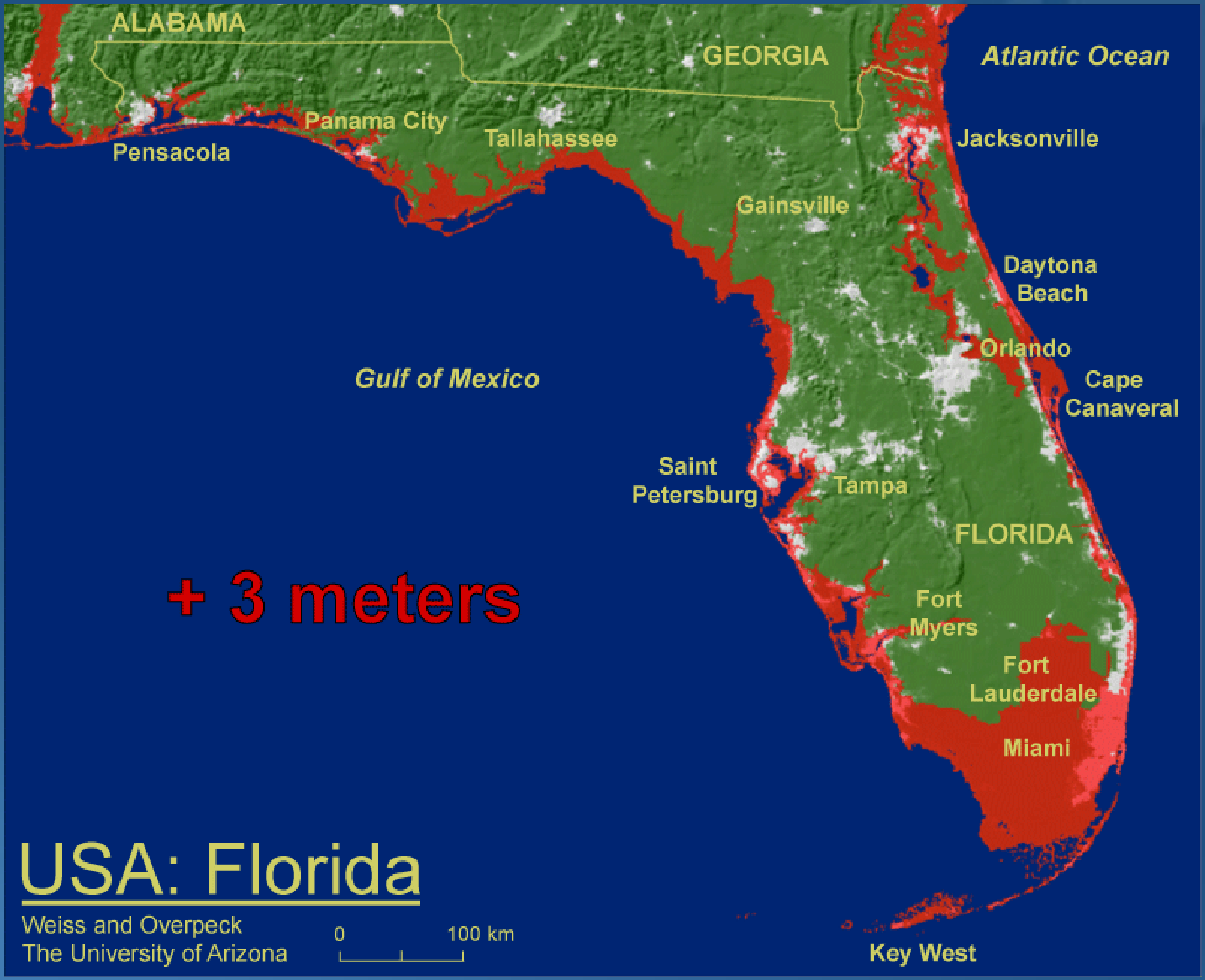
Impact of a 1-meter rise in sea level. Graphic: Weiss and Overpeck, U. of Ariz.

Sea level rise



Impact of a 2-meter rise in sea level. Graphic: Weiss and Overpeck, U. of Ariz.

Sea level rise



Impact of a 3-meter rise in sea level. Graphic: Weiss and Overpeck, U. of Ariz.

Elevating buildings above the ground

Post-Katrina home in New Orleans' Lower 9th Ward built through the Make it Right Foundation. Photo: Alex Wilson

- Most important in flood-prone areas
- Can use pier foundations
- Break-away coverings on piers
- Easiest in retrofits, but can elevate existing buildings

Elevating mechanical equipment

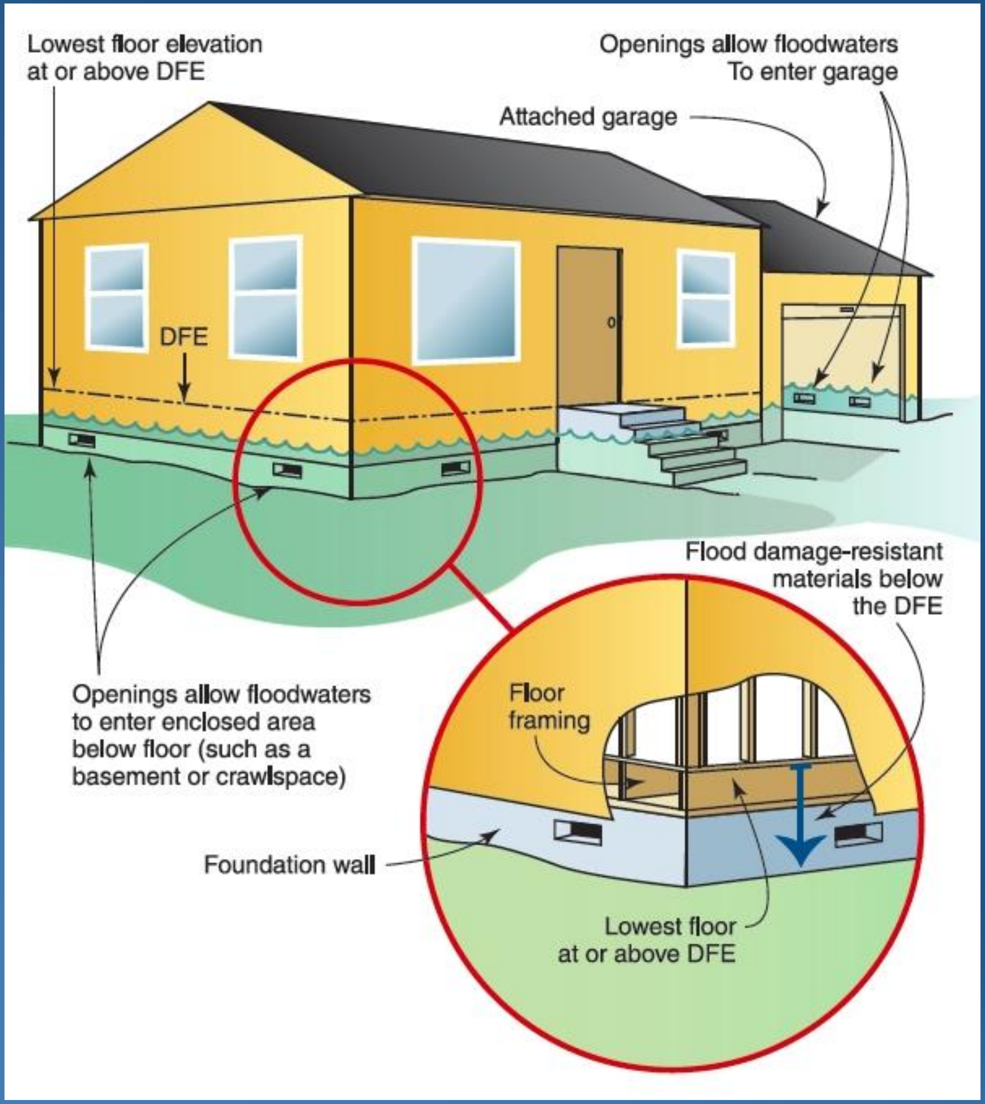
Elevating mechanical equipment in Carolina Beach, NC. Photo: Dave Saville, FEMA

Specifying materials that can survive wetting

Georgia-Pacific Dens Element

Polished concrete floor - RetroPlate photo

Wet floodproofing



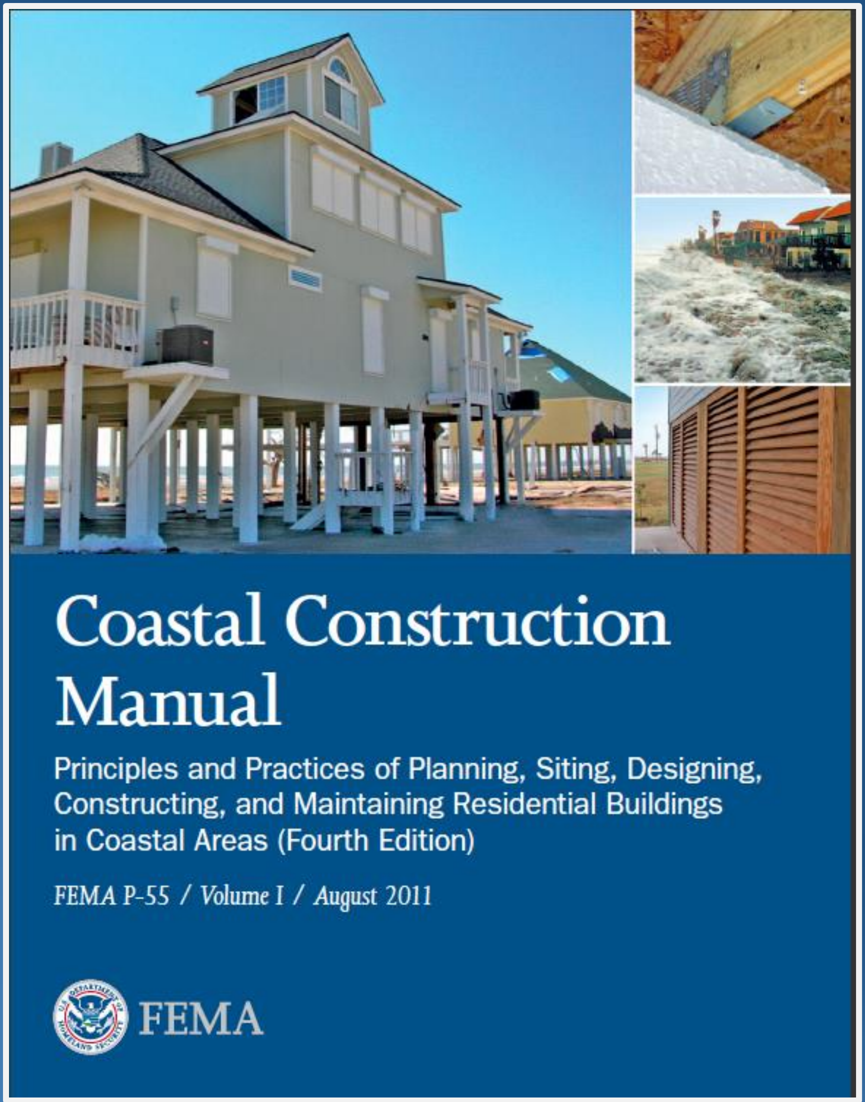
FEMA

- Allowing floodwaters to flow into a basement or through a building
- Prevents hydrostatic pressure from knocking the building down
- Recommended by FEMA for residential and most commercial buildings

Dry floodproofing – keeping water out

Flood barriers on a commercial building in Providence, RI
Photo: Alex Wilson

Floodproofing guidance

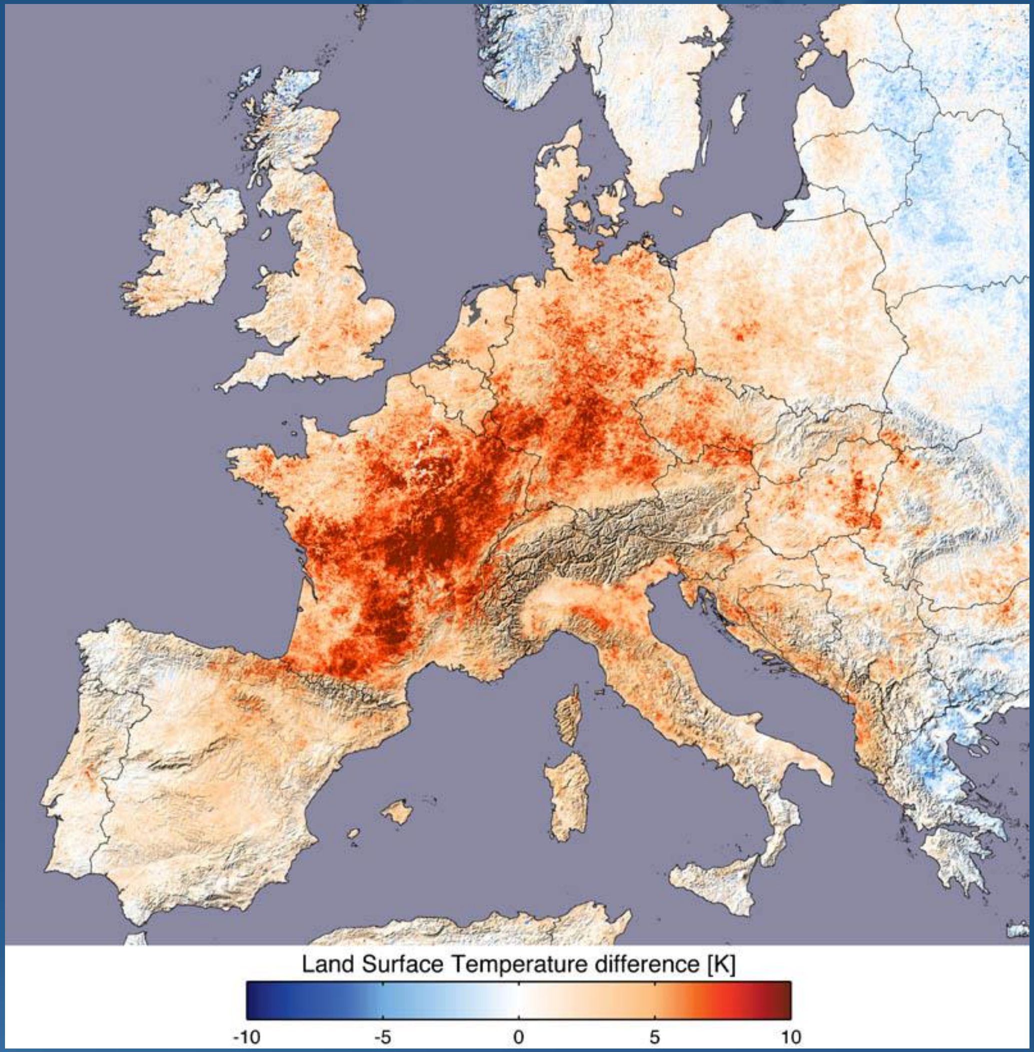


FEMA

- Lowest floor at BFE + 5 (five feet above base flood elevation)
- Meet or exceed the IBHS Commercial Risk Engineering Bulletin for Flooding
- Engineered to achieve comparable standards

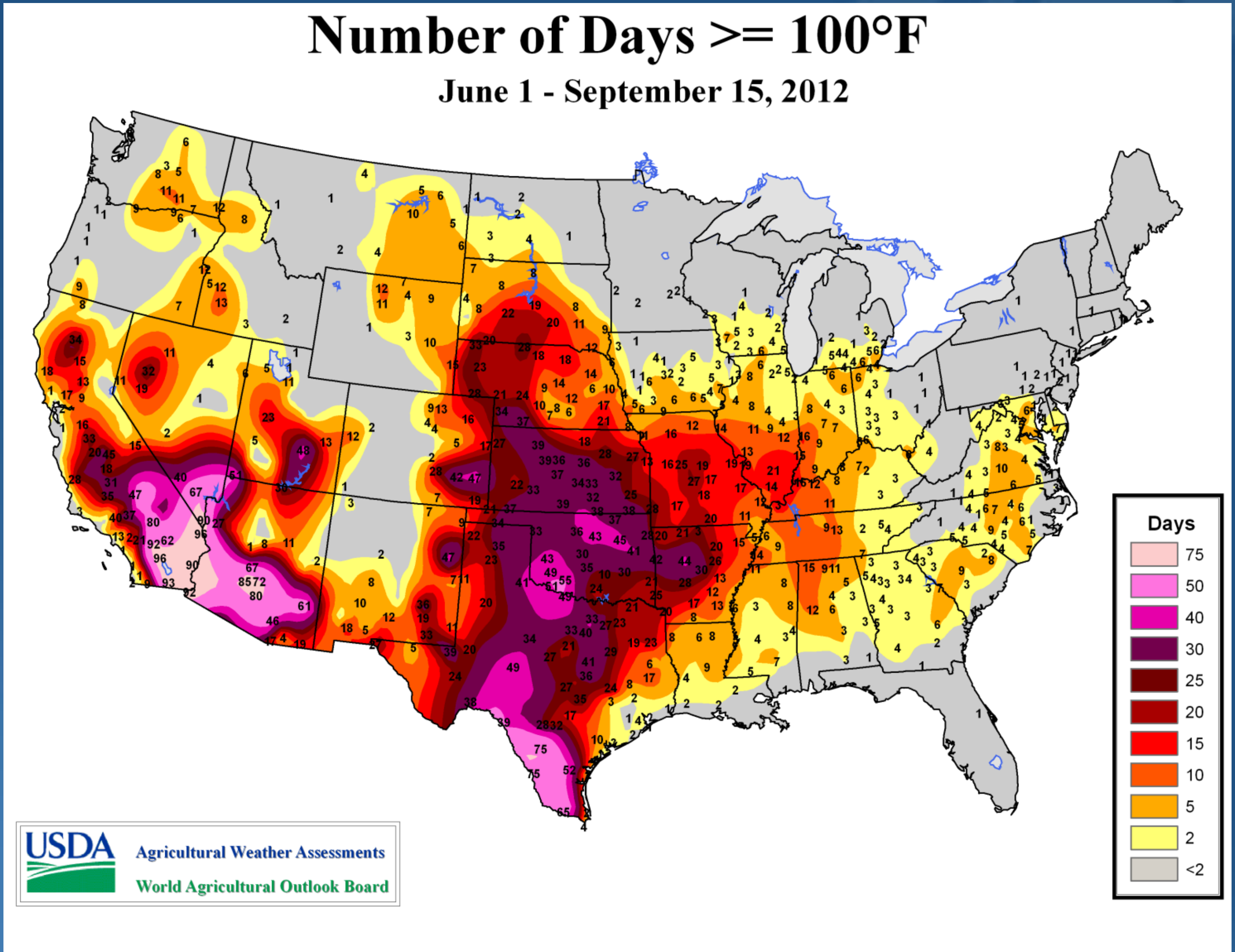
Temperature extremes

- As temperatures rise, heat waves will also increase in frequency, severity, and duration
- Can lead to significant increase in fatalities
- Elderly people most vulnerable
- Over 30,000 deaths in Europe in 2003
- 750 deaths in Chicago in 1995



Summer 2003 temperature extremes in Europe – NASA Earth Observatory

Heat Waves to become more common



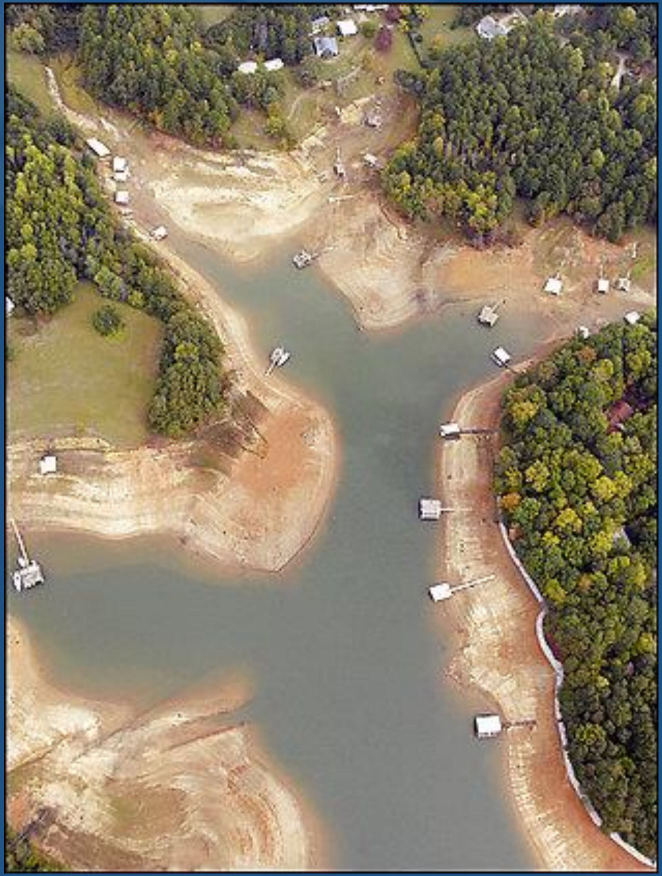
Mechanical systems for a hotter climate

An 18,000 Btu/hour air-source heat pump for heating and cooling our net-zero-energy house in Vermont. While I rarely need air conditioning today, that might be very different in a few years.

Photos: Alex Wilson

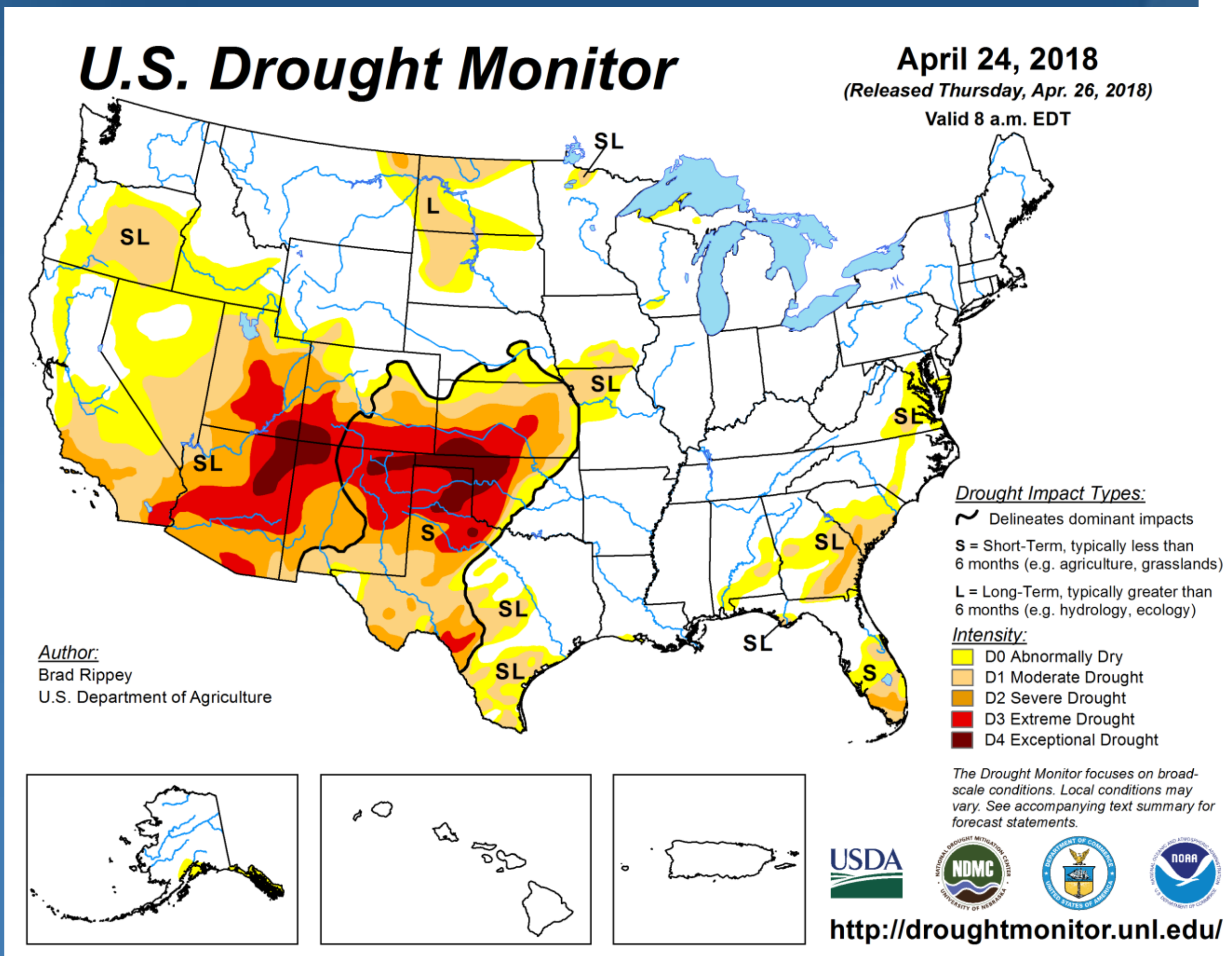
Drought & Water Shortages

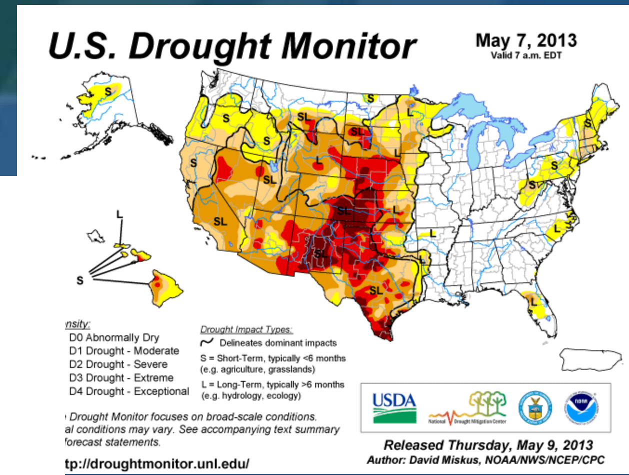
Lake Mead, October 2007, Ken Dewey photo



Lake Lanier, September, 2007
Washington Post photo

U.S. Drought Conditions





Source: National Drought Mitigation Center - University of Nebraska - Lincoln

Minimizing Water Consumption

Niagara Stealth 0.8 gpf vacuum-assist toilet

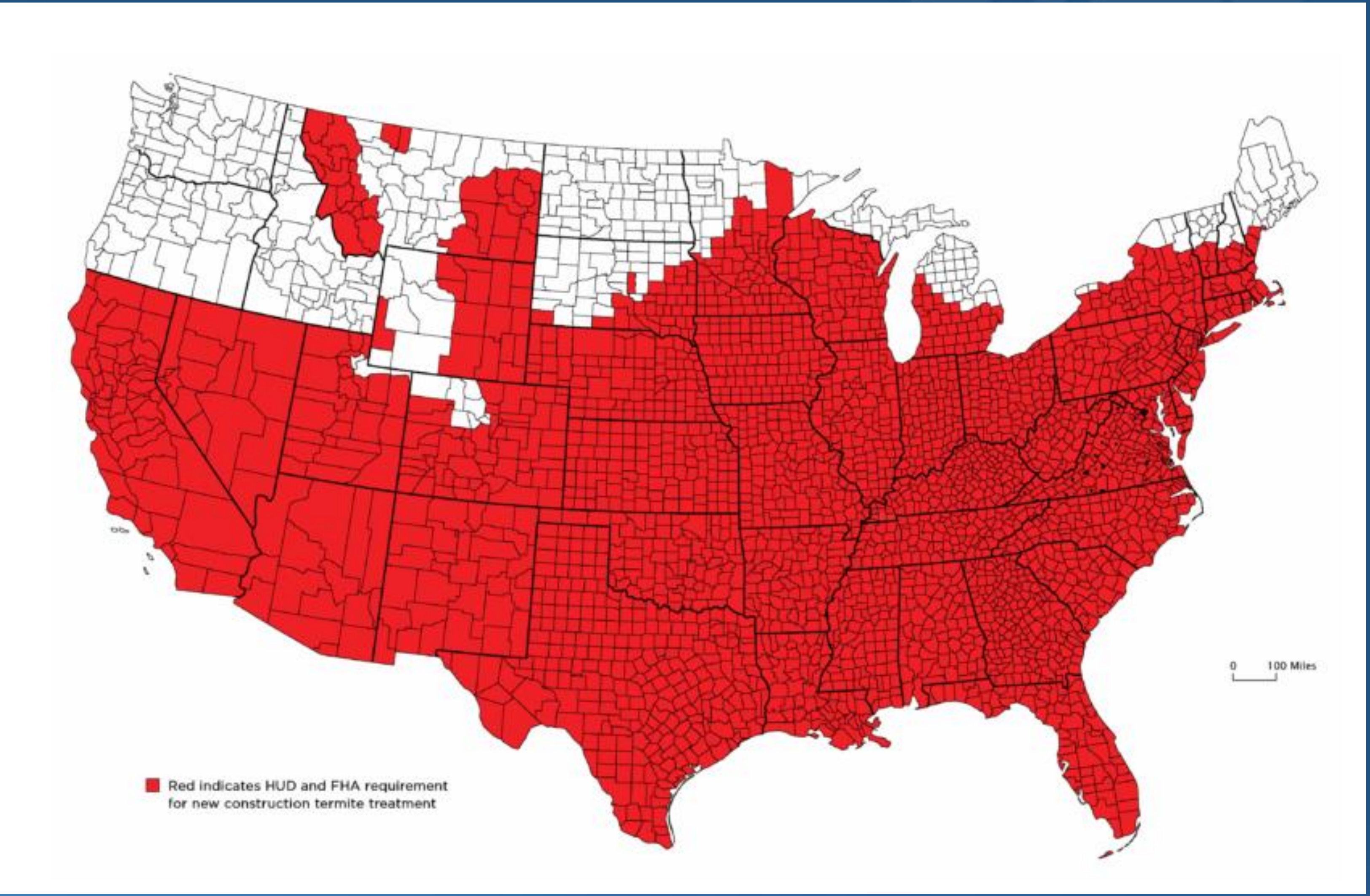
Delta H2Okinetics 1.5 gpm showerhead

Xeriscaping near Phoenix - Photo: Alex Wilson

Water conservation guidance

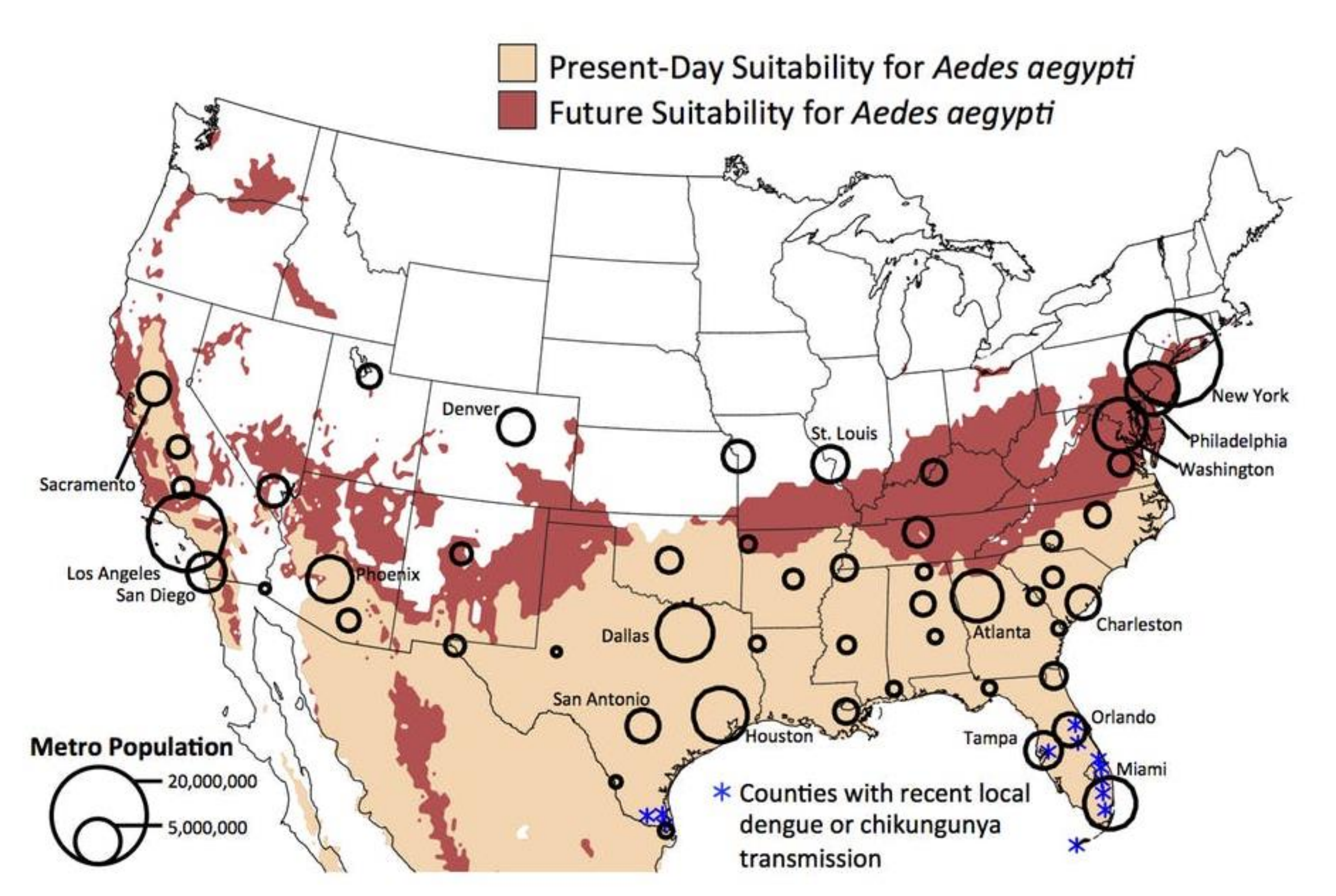
- Water efficiency credits in the LEED Rating System
- Landscape water conservation in the SITES Rating System
- WaterSense standards for plumbing fixtures

Insect ranges moving north



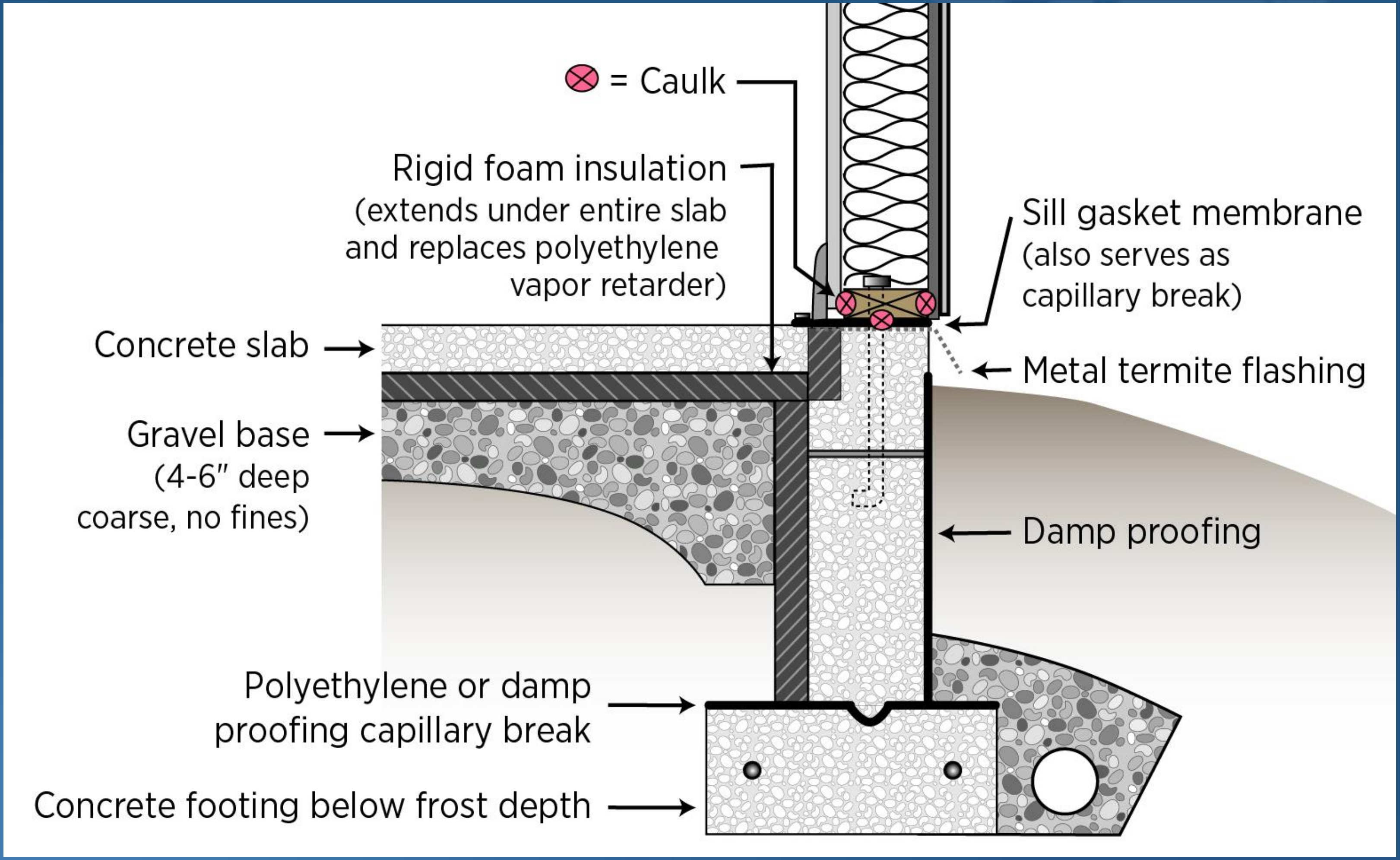
Ranges of some insects are extending north, including termites. Map: Nisus Corporation

Insect ranges moving north



Map showing the range of the Aedes aegypti *mosquito, which transmits viruses causing Zika, Dengue and other viruses, for present-day (1950-2000) and future (2061-2080; RCP8.5) conditions. Map: Andrew Monaghan, Univ. Corp. for Atmospheric Research*

Design strategies for insects



Example of termite flashing in a typical construction system. Graphic: Pacific Northwest National Laboratory for the Building America Solutions Center

Design strategies for insects

- Lots of options with insect screens
- Shown here is a Larsen integral storm-screen window being installed
- The screen rolls up into a valance at the top of the window and is hidden from view when not deployed
- Can be operated from inside the house

Photo: Alex Wilson

Power Outages – Impact of any disaster

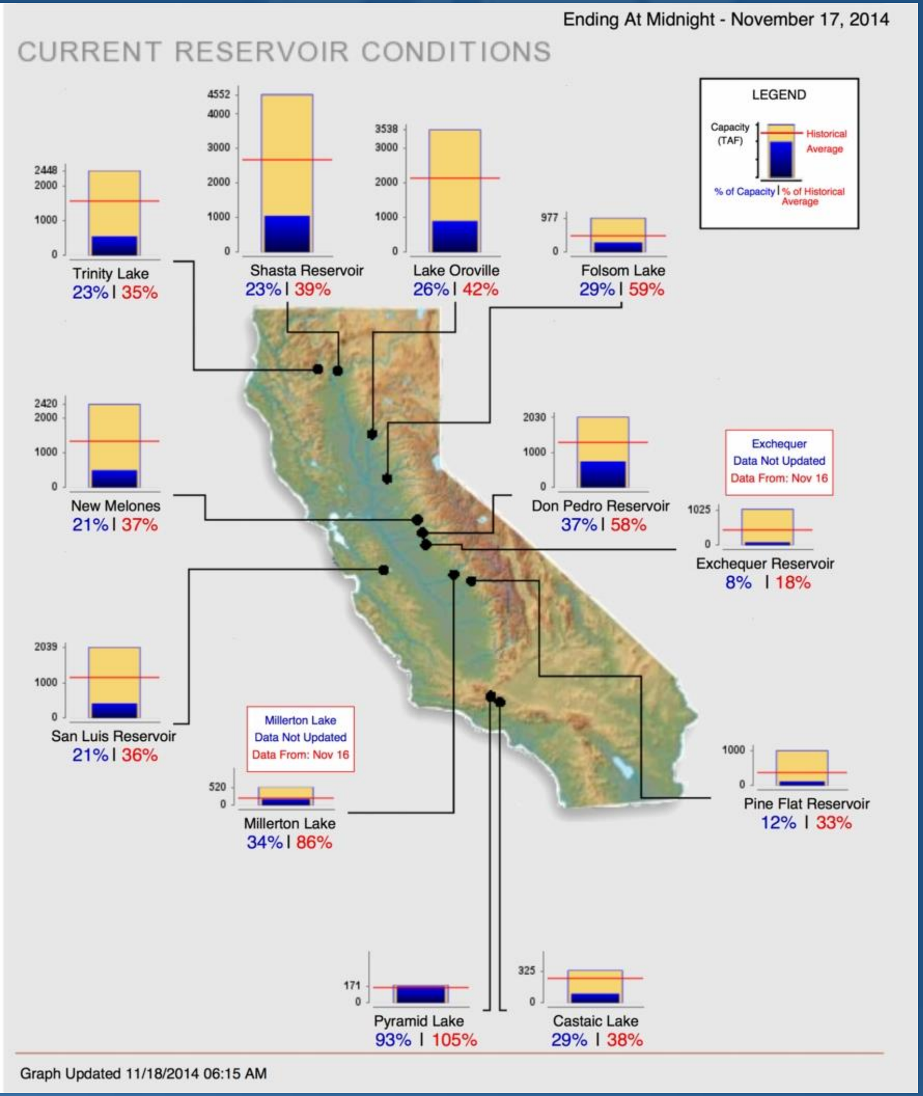
Blackout caused by Hurricane Sandy on October 29, 2012 – photo: Eric Chang

Vulnerabilities with energy production and distribution in the U.S.

- 160,000 miles of high-voltage power lines
- 3,400 power plants
- 150 refineries, half in the Gulf Coast
- 2.5 million miles of oil and gas pipelines

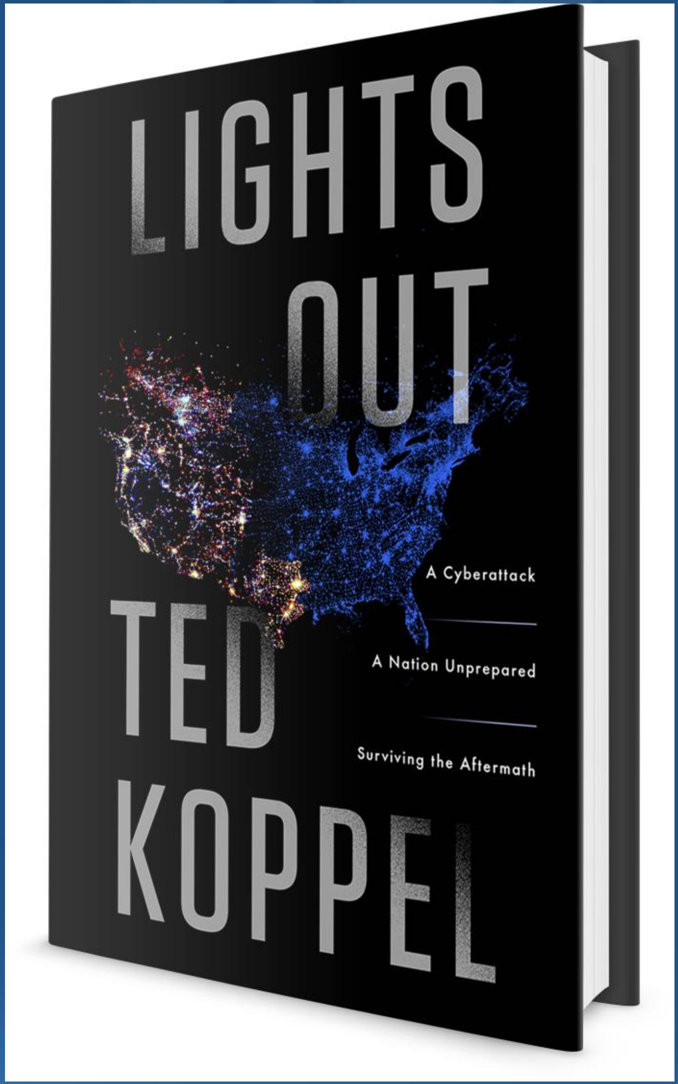
Drought Puts Power Plants at Risk

- 89% of U.S. electricity generation from thermal-electric power plants
- 40% of U.S. fresh water extractions in the U.S. used for power plants
- Vast majority of power plants on rivers
- One TVA nuclear plant in Alabama shut down briefly in 2007 due to low water
- In 2003 drought and heat wave in Europe - more than a dozen plants shut down or output reduced



Other vulnerabilities

- The issue of cyberterrorism has gained a lot of interest recently
- Ted Koppel's 2016 book *Lights Out* lays out the dangers



Cascading impacts of power outages

Gas line in Woodbridge, NJ on November 1, 2012 – photo: AP

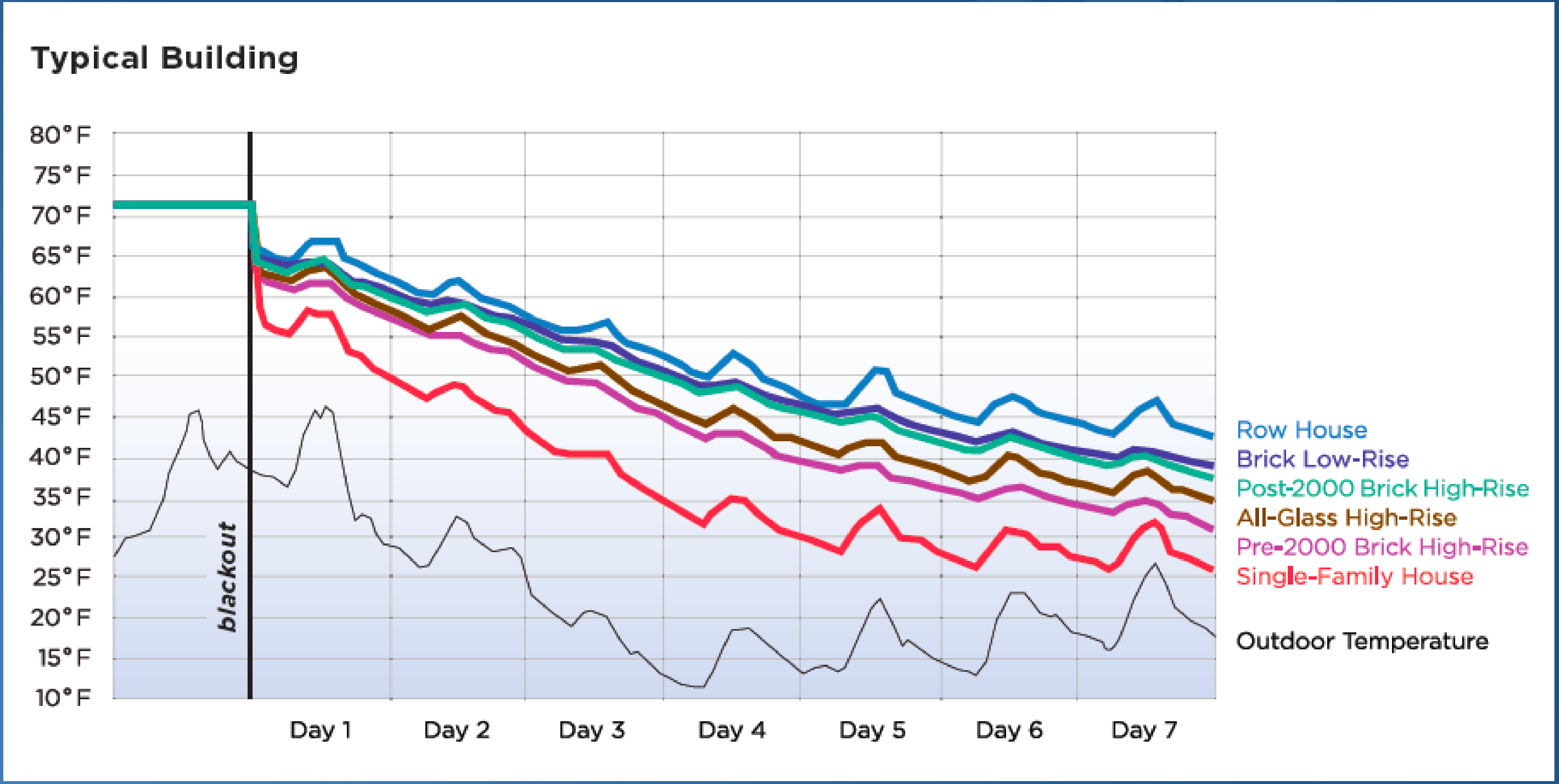
Even those with generators vulnerable

Gas line in New Jersey, November 1, 2012 – photo: Getty Images

Keeping occupants safe in a building that loses power: passive survivability

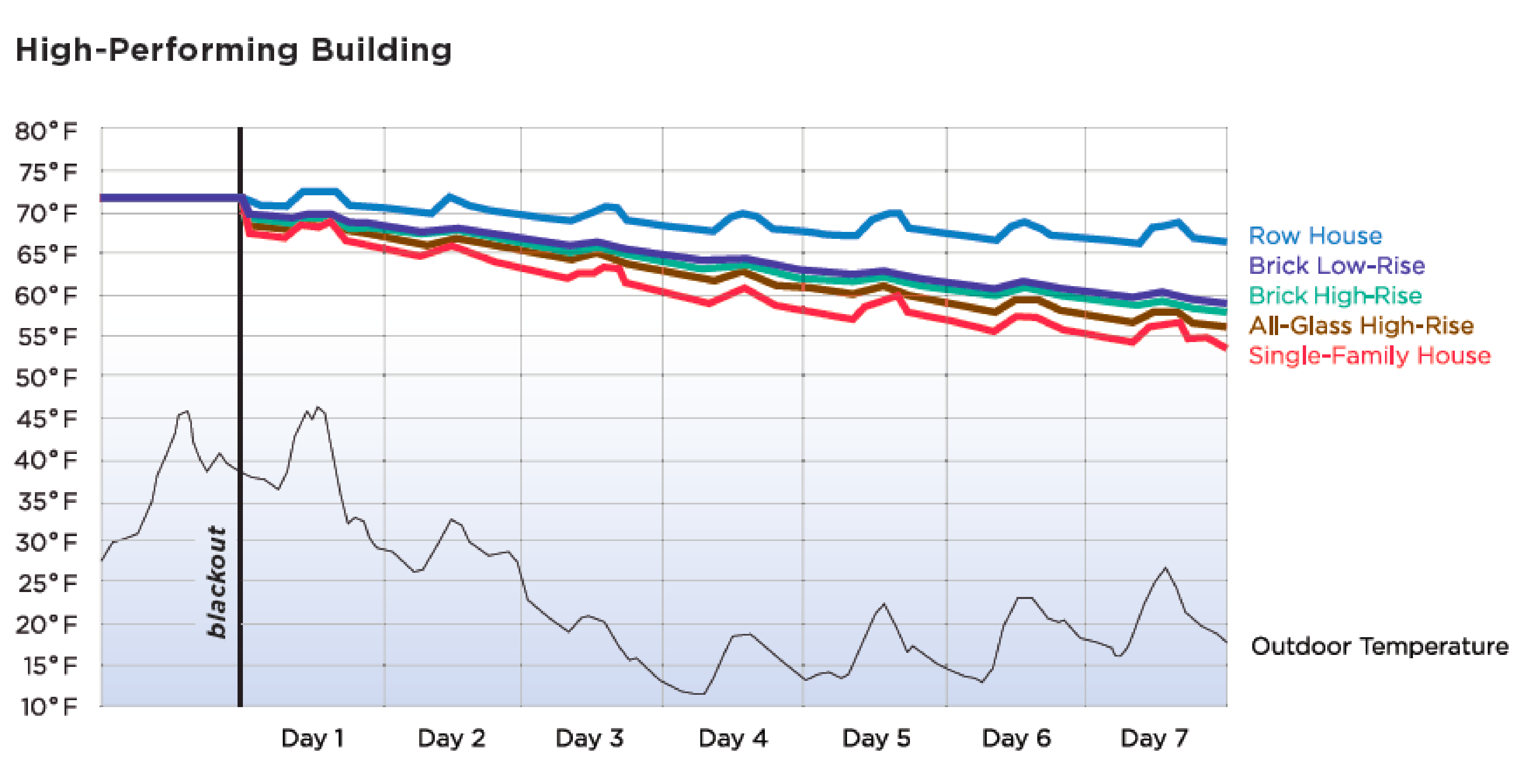
Wintertime thermal image of a Passive House in Brooklyn, NY. Reds and yellows indicate higher surface temperatures. Very little heat is being lost from the row house in the center, which has been retrofit to meet Passive House standards. Photo: SGBUILD.com

Drift temperatures during outages - winter



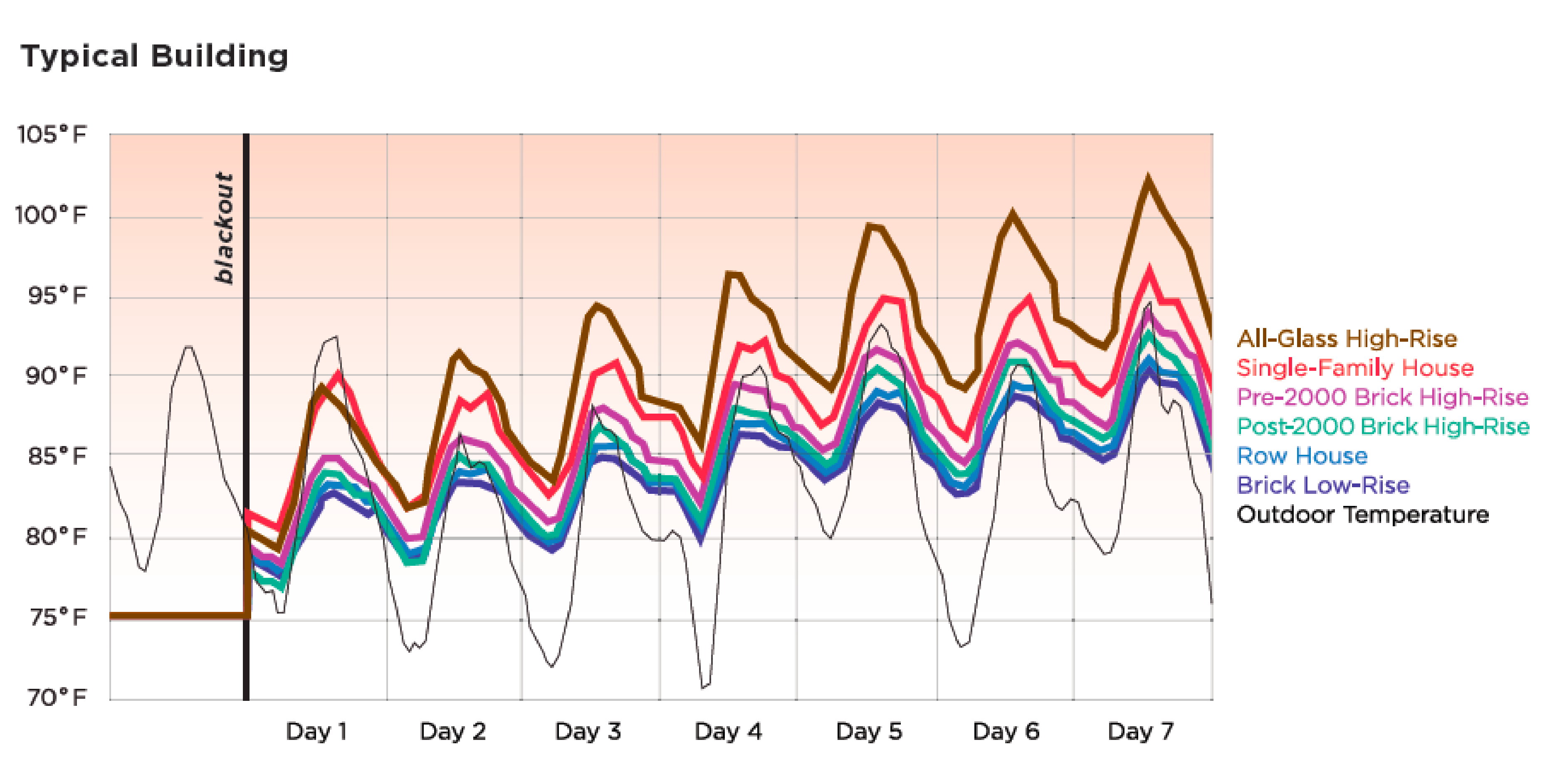
Temperature modeling by Atelier Ten for the report "Baby It's Cold Inside," Urban Green, NYC

Drift temperatures during outages - winter



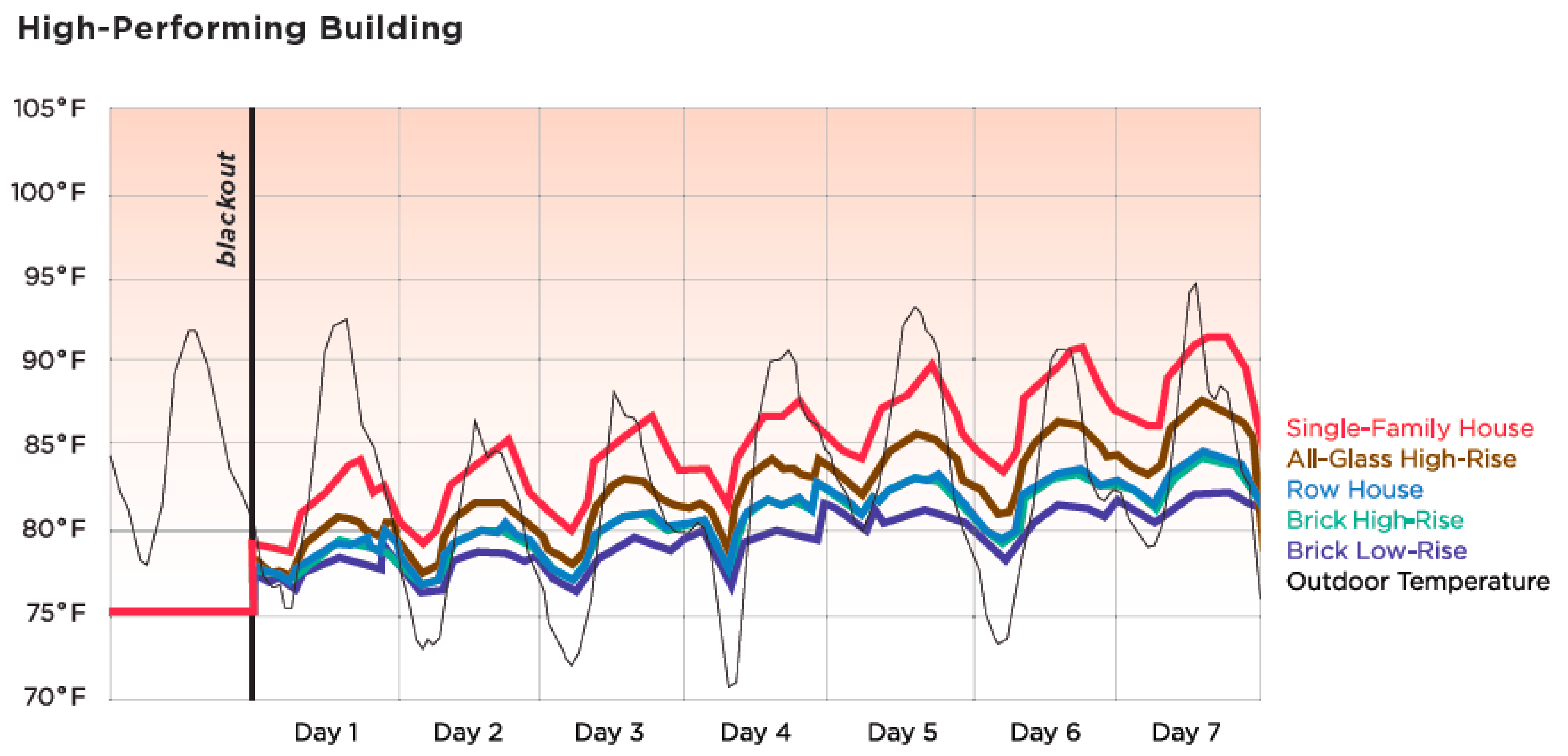
Temperature modeling by Atelier Ten for the report "Baby It's Cold Inside," Urban Green, NYC

Drift temperatures during outages - summer



Temperature modeling: Atelier Ten, New York City in "Baby It's Cold Inside," Urban Green Council

Drift temperatures during outages - summer



Temperature modeling: Atelier Ten, New York City in "Baby It's Cold Inside," Urban Green Council

Maintaining habitable temperatures

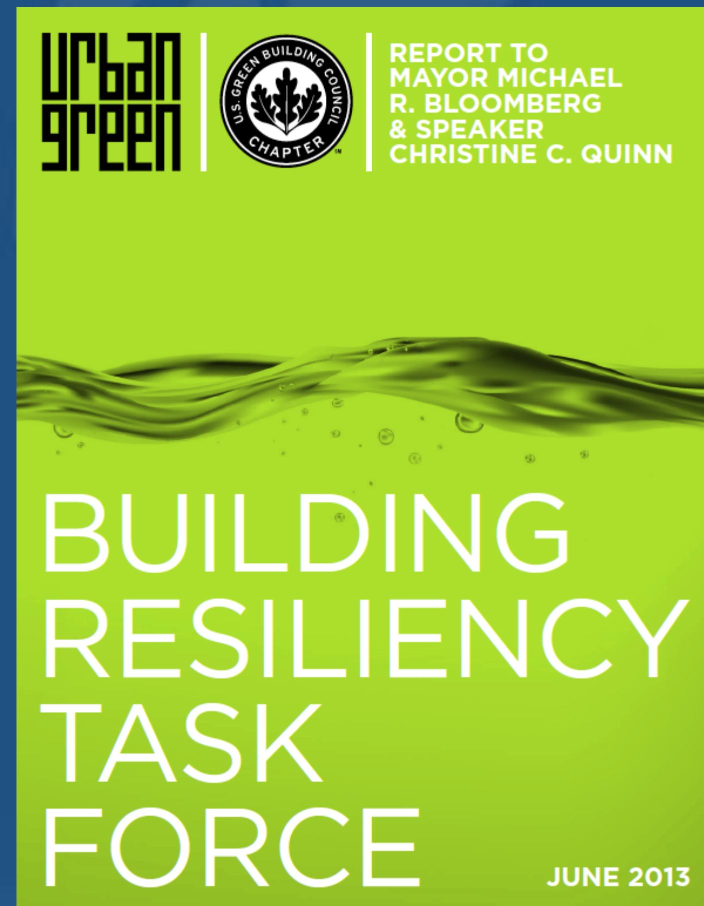
27 Maintain Habitable Temperatures Without Power

Issue: Utility failures often disable heating and cooling systems, leaving interior building temperatures dependent on whatever protection is provided by the insulation and air sealing of a building's walls, windows, and roof.

Recommendation: Extend the mandate of the Task Force through Fall 2013 to develop a multiyear strategy for ensuring that new and substantially altered buildings maintain habitable temperatures during utility failures. Clarify requirements for tightly sealing new windows and doors and upgrading roof insulation during roof replacement.

✚ further action

Recommendation from the Building Resiliency Task Force



Building Resiliency Task Force in New York City – Final Report, June, 2013

Defining "passive survivability" or "thermal habitability"

May 2013 RDI charrette in NYC on metrics of passive survivability. Photo: Alex Wilson

BRI Building Research & Information 2016
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INFORMATION PAPER

Overheating and passive habitability: indoor health and heat indices

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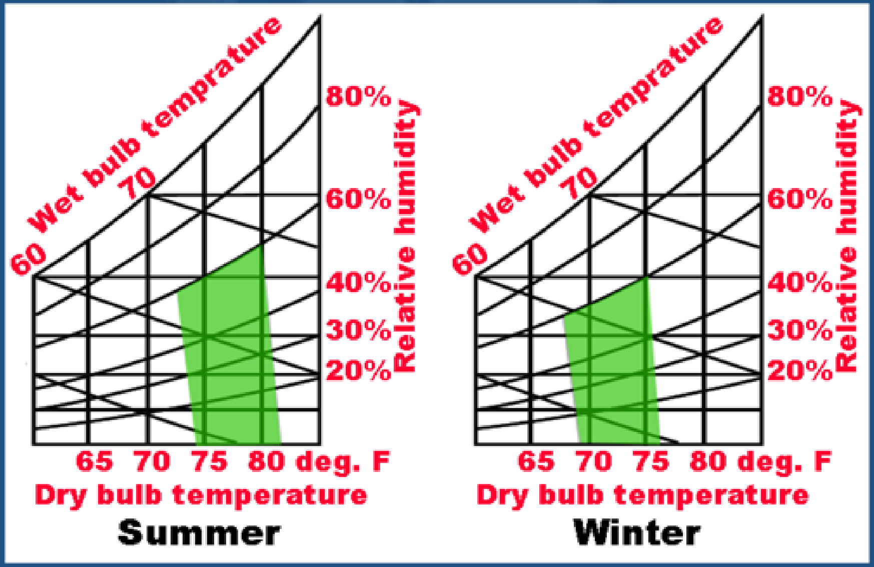
As extreme heat and weather events are predicted to increase due to global warming, the risk of human heat stress within buildings will increase. To be resilient, buildings will need the capacity to provide habitable indoor conditions without power for limited amounts of time. Additional indoor thermal standards are required for public health to address 'passive habitability' during power outages. Current research on building-related heat stress and numerous heat indices is examined in relation to the development of a new heat-safety metric for use in passively conditioned buildings. Most indoor overheating research relies on outdoor temperature data and has no common indoor heat index for evaluating indoor heat stress. A recommendation is made for using the wet-bulb globe temperature (WBGT) and predicted heat strain (PHS) indices for modelling and monitoring of indoor heat stress in healthy adult populations because both indices utilize the primary thermoregulation variables, have associated heat-stress thresholds, and can be assessed or tracked with existing environmental monitoring methods and predictive energy modelling techniques. Further research is recommended on health effects and exposure limits of vulnerable populations, and the variation in thermal factors within buildings and the building stock.

Defining the "Habitability Zone"

- Different from "Comfort Zone"
- "Habitability Zone" much wider
- Influenced by temperature, humidity, mean radiant temperature
- You can evaluate using SET temperature (Standard Effective Temperature)
- For the LEED pilot credits on resilient design, we defined safe range: a low of 54°F SET to high of 86°F SET
- We also defined how much time a building can deviate from that habitability zone
- Based on limited physiological data



Conventional "Comfort Zone"
Jonathan Ochshorn, 2010

Sample requirements for Passive Survivability or Thermal Resilience

Requirements:

- Demonstrate through thermal modeling that a building will maintain "livable temperatures" during a power outage that lasts 7 days during peak summertime and wintertime conditions of a typical year.

Key Definitions:

Standard Effective Temperature:

SET factors in relative humidity and mean radiant temperature

Habitable Zones: Defined by team

Occupant Density: necessary to accommodate the total building population in the habitable zones.

Ventilation: All habitable zones must have access to natural ventilation

Habitable temperature:

- Cooling: Not to exceed 9 °F SET-days (216 °F SET-hours) above 86°F SET for residential buildings.
- Cooling Not to exceed 18 °F SET-days (432°F SET-hours) above 86°F SET for non-residential buildings.
- Heating: Not to exceed 9 °F SET-days (216 °F SET-hours) below 54° SET for all buildings.

Spaulding Rehab Hospital, Boston, MA

Photo: Perkins+Will

Spaulding – protection from flooding

Photo: Perkins+Will

Spaulding – floodable first floor

- Wet floodproofing
- 100% wettable materials (tile, polished concrete, etc.)
- Therapeutic pool
- Therapeutic exercise area with portable equipment
- Avoidance of mechanical systems

Photo: Spaulding Rehab Hospital

Spaulding – operable windows

Photo: Alex Wilson

Photo: Anton Grassl/Esto, Courtesy of Perkins+Will

Spaulding – elevated equipment

- Utility service in penthouse floor
- Rooftop CHP system
- Chillers, air handlers, ventilation, boilers in two penthouse floors
- Two back-up generators in penthouse - either could operate hospital
- Most diesel fuel stored in basement - bunkerized

Photo: Alex Wilson

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