The Impact of Increasing Severe Weather Events on Shelter

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The Indoor Environments Division
Office of Radiation and Indoor Air,
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Prepared by:
Terry Brennan
Camroden Associates

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Note: This report presents the findings, recommendations and views of its author, it does not necessarily reflect the opinion, approval or endorsement by the U.S. Environmental Protection Agency.

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The 2009 report *Global Climate Change Impacts in the United States* (CCSP 2009) predicts that severe weather events will increase in frequency or severity. The authors forecast:

- More days hotter than 90°F (Figure 1).
- Increased drought and wildfire conditions.
- More extremes in rainfall (Figure 2).
- Increased frequency and intensity of hurricanes, tornadoes, ice and snow storms and consequent floods and loss of electric power (Figure 3).

Figures 6, 7 and 8 clearly show that extreme weather events are already becoming more frequent. As this trend continues, people will need shelter from the increasingly severe weather. Extended periods of temperatures over 90°F, which result in increased deaths (Margolis 2008), are expected to increase across the U.S. Droughts will be more frequent in the western states. Wildfire frequency has increased dramatically in western states with hotter dry seasons and stronger winds. This development argues for fire-protective houses and landscaping.

Increases in very heavy rains, hurricanes and other extreme storms are likely to result in more frequent and extensive flooding and, when the rains do not lead to floods, to more moisture problems in buildings. Electric power and other utility services are often interrupted during and after extreme storms and flooding. Here are some examples of the impact of extreme weather:

- Heat Waves
    - In 1995 about 700 people in Chicago were killed by a heat wave during one week.
    - In Europe 70,000 deaths in 2003 were related to high temperatures (from Report on Excess Mortality in Europe, Summer 2003, and European Public Health Commission).
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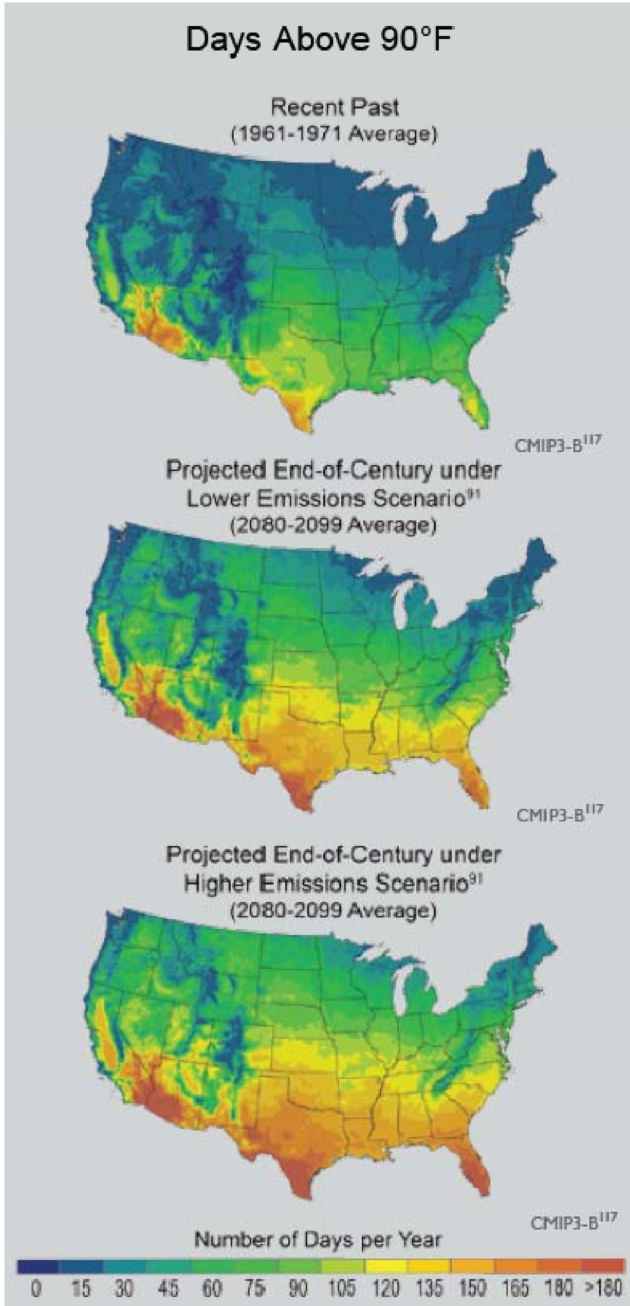
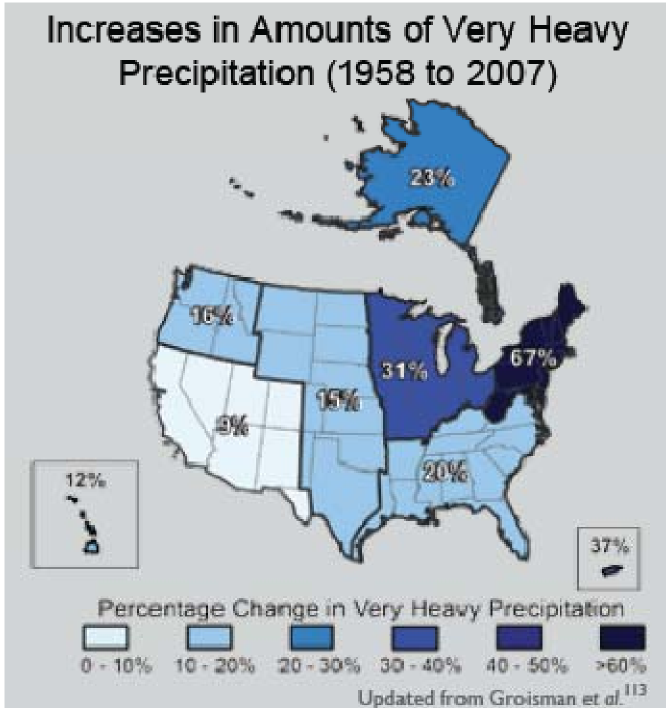
- On August 29, 2005, Hurricane Katrina killed more than 1,600 people, destroyed 200,000 homes and displaced about 3 million people. Temperatures in the New Orleans Superdome, which served as an emergency shelter, rose to 105°F. Drinking water supply and sanitation services were not operating.
- Seven Midwest states recently experienced severe flooding and 36,000 people were evacuated.
- Ice Storms
    - The Blizzard of 1978 killed 17 people and left tens of thousands in northern states without heat and water.

  - A 1998 ice storm in eastern Canada killed 28 people, left 4 million people without power and displaced 600,000 residents from their homes. Three weeks later, 700,000 people still did not have power.
  - A 2005 ice storm left over 700,000 people in Georgia, North Carolina and Virginia without electric power for more than a week.
  - In 2007 ice storms left over 500,000 people without power in Oklahoma, Illinois, Kansas, Missouri, Texas, Mississippi, Michigan, New York and New Hampshire. Many locations were without power for several days.
- Blackouts
  - The possibility of blackouts like the one New York City experienced in August 2003 make electricity and fuel distribution systems vulnerable.
  - A blackout in July 1977 left 9 million people in New York City without power for up to 25 hours.
  - The Blackout of 2003 affected 10 million people in Ontario, Canada, and 50 million people in the U.S. for two days.



The average number of days per year when the maximum temperature exceeded 90°F from 1961-1979 (top) and the projected number of days per year above 90°F by the 2080s and 2090s for lower emissions (middle) and higher emissions (bottom).[91] Much of the southern United States is projected to have more than twice as many days per year above 90°F by the end of this century.

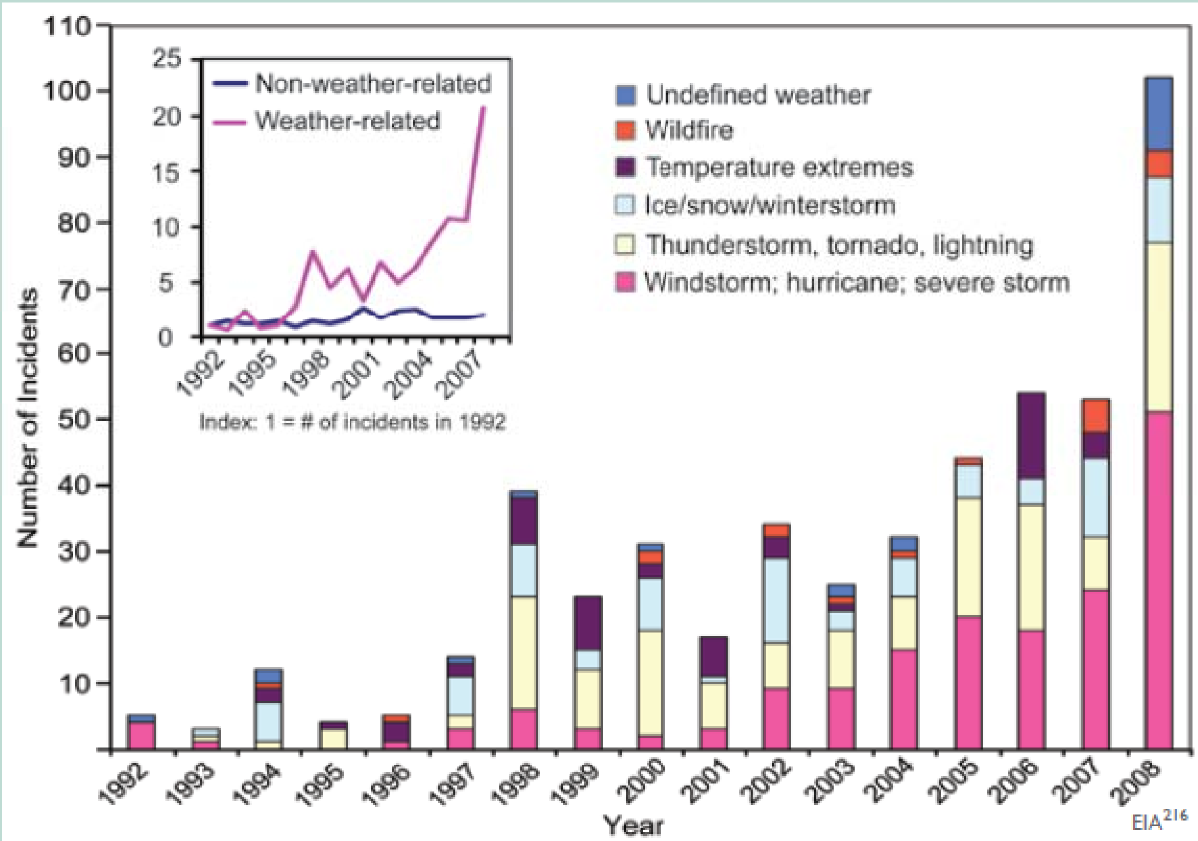
Figure 1. Number of days per year over 90°F under low greenhouse gas emission and high greenhouse gas emissions (CCSP 2009)



The map shows percent increases in the amount falling in very heavy precipitation events (defined as the heaviest 1 percent of all daily events) from 1958 to 2007 for each region. There are clear trends toward more very heavy precipitation for the nation as a whole, and particularly in the Northeast and Midwest.

Figure 2. Increases in very heavy precipitation (CCSP 2009)

Significant Weather-Related U.S. Electric Grid Disturbances



The number of incidents caused by extreme weather has increased tenfold since 1992. The portion of all events that are caused by weather-related phenomena has more than tripled from about 20 percent in the early 1990s to about 65 percent in recent years. The weather-related events are more severe, with an average of about 180,000 customers affected per event compared to about 100,000 for non-weather-related events (and 50,000 excluding the massive blackout of August 2003).[201] The data shown include disturbances that occurred on the nation's large-scale "bulk" electric transmission systems. Most outages occur in local distribution networks and are not included in the graph. Although the figure does not demonstrate a cause-effect relationship between climate change and grid disruption, it does suggest that weather and climate extremes often have important effects on grid disruptions. We do know that more frequent weather and climate extremes are likely in the future,[68] which poses unknown new risks for the electric grid.

Figure 3. Significant disturbances in the US electric grid from 1992 to 2008. (CCSP 2009)

As weather extremes increase in larger areas of the country, buildings in general and emergency shelters in particular will have to continue to provide protection in the face of more extreme conditions. The implication for building design and renovation is that buildings in many new locations must be able to:

- Survive strong winds, heavy rains, floods and increased wildfire risk
- Provide acceptable:
    - temperatures
    - drinking, bathing, cooking and cleaning water

- toilets
- ventilation
- food preparation
- in a variety of emergency shelters without electric power for extended periods.

Private and public groups that provide aid during weather-related emergencies have published guidance for shelter requirements during and after extreme weather events (FEMA 2008, ICC 2009, ARC 4496). The guidance covers tornadoes, hurricanes, floods and extended heat waves. In areas of the U.S. that historically have experienced tornadoes, hurricanes and floods, building codes and the emergency response community already address the integrity of buildings and problems of evacuation, sanitation and shelter For example, the Gulf Coast states have building code requirements that must accommodate the extreme winds that are the hallmark of hurricanes (Florida SERT 2010, Louisiana OEP). As storms have become more frequent and severe the emergency response community has identified a need for additional shelters and guidance: "Hurricane shelter surveys and regional evacuation studies have determined that there are hurricane shelter space deficits in many regions. Though there has been significant progress in reducing the deficit, school boards and other partners continue to need guidance to best utilize available resources." (Florida SERT 2010).

Existing guidance is geared towards shelters that operate for short periods of time and provide protection for specific events such as tornadoes, hurricanes, floods and extreme heat. Emergency shelters are expected to be occupied for a few hours during tornadoes and for 24 hours during hurricanes. Therefore, available guidance does not cover providing habitable space for extended periods of time. Current guidance for extreme heat events depends on air conditioned shelters being available. The US Green Building Council is the only source of guidance on designing buildings to provide more robust shelter in the face of increasingly severe weather (USGBC 2005).

Given the increase in electricity disruptions, the large affected areas and the extended periods of time without electric power, existing codes and guidance could be augmented to expand the scope of shelter during and after weather-related emergencies. Alex Wilson proposed the idea of "passive survivability" to address emerging extreme-weather issues (Wilson 2006, USGBC 2005). At its heart, passive survivability is designing buildings and communities to provide livable conditions in the event of extended power outages, interruptions of fuel supply, or the loss of water and sewer services. There are two strategies for achieving passive survivability:

- Design buildings to provide services for several days with no electric power. Design buildings to provide services with a small amount of reserve electric power.

Maintaining temperature in the absence of electric power

Identify the allowable high and low temperatures. For example, in cold weather the indoor temperature target may be no less than 55°F. In hot weather the indoor air may be no more than 82°F. If the electric power goes out or the fuel supply is interrupted, a building's indoor temperatures will drop if it is colder outside than inside.

A well-sealed and heavily insulated building that has effective thermal mass inside will take a long time to cool down when the heat goes off and a long time to warm up when the air conditioning goes off. The heat given off by people in the building will help maintain indoor temperatures when it is cold outside, but will cause the building to warm up more quickly during hot weather. Most building simulation software can model the amount of time it will take for a building to reach the minimum or maximum allowable temperatures if power is lost and the heating or air conditioning fails.

The earth can be used to buffer temperatures. If a shelter is slab on grade or in a basement, the earth contact provides a similar thermal mass effect: as the indoor temperature drops below the earth temperature, heat transfers from the slab or basement walls into the space.

It is best to locate shelters outside flood hazard zones. Within flood hazard zones below-grade spaces must be elevated above the storm surge and flood levels (FEMA 2008).

Designing a building that takes days to drift out of the acceptable temperature range has many elements in common with designing a low-energy-use building. The foundation of low-energy use buildings is a tightly sealed, heavily insulated enclosure with windows that provide good insulation and reject unwanted solar heat gains. The strategies work both for reducing greenhouse gas emissions and for providing robust thermal protection in emergencies.

Providing water and toilets

Water is needed in emergency shelters first and foremost for drinking and must be of high quality. Storing drinking water at the shelter continues to be the best strategy. In situations that extend past a few days, stored rainwater can be used for non-potable purposes such as flushing toilets provided the sewer system is operational. Systems that treat collected rainwater can be designed to provide water for cleaning, bathing and cooking. Rainwater stored inside the shelter could provide thermal mass (albeit progressively diminishing thermal mass).

Current guidance requires toilets for all shelters, even those expected to be occupied for only a few hours (FEMA 2008). If the sewage disposal system is expected to be operational during emergencies, flush toilets can be used. Low-flow toilets and waterless urinals can be used to extend the amount of time stored rainwater will last. An even more robust solution is to provide composting toilets.

Ventilation and lighting

Existing guidance requires ventilation in shelters that meets current building codes (FEMA 2008). Ventilation is needed to dilute contaminants originating inside the building, including those given off by the occupants and by materials and equipment inside the building. There are two difficulties in providing ventilation for extended times in shelters. First, most buildings except single-family residences are ventilated by electric fans that move air through the building. Second, outdoor air flowing through the building speeds up the rate at which the indoor temperature drifts towards the allowable minimum or maximum. There are two approaches for dealing with the first issue: design a passive ventilation system that uses no fans, or design a ventilation system that has passive features and uses very low-wattage fans powered by a photovoltaic array or batteries. Although passive ventilation is an ancient technology, there are very few well-documented case studies of its performance. Lighting can be provided using daylighting techniques and supplemented with photovoltaics and battery backup.

Food preparation

Food will have to be stored at the shelter. Meals that can be prepared without cooking will be needed. There are advantages to being able to boil water, so storing stoves and fuel on site is the most practical solution.

Conclusion

Incorporating passive survivability features into new and renovated buildings has the dual benefit of providing emergency shelter for extended periods and reducing greenhouse gas emissions from buildings. Because low-energy-use buildings and shelters that can tolerate loss of power share many strategies, it is possible that more buildings can be designed to shelter occupants in place and help meet the increasing need for emergency shelter. For example, multifamily buildings could be designed to provide emergency shelter for residents in urban areas. While this paper focuses on buildings, the US Green Building Council proposes adopting passive survivability as part of a broader policy to make communities more resilient to disasters related to extreme weather (USGBC 2005). The 10 point list for the hurricane-prone Gulf Coast proposed by the USGBC includes the building-related features discussed here and adds community-level efforts including:

- Providing back-up power for municipal sewage systems. Using distributed power, water and communications services. Installing solar electric and solar thermal systems. Placing all new utility distribution lines in flood-protected underground conduits. Adding public emergency shelters to the existing stock. Upgrading highways to withstand Category 5 storms.

Many of these ideas can be applied to areas outside the Gulf Coast, but the design criteria for surviving storms will be less stringent for areas that are not expected to experience hurricanes.

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