Impact of Hurricanes on Health Care Facilities

CR4HC

3. Assessment and Remediation of Vulnerabilities in Infrastructure and Operations

Tropical storms like hurricanes often leave in their wake a long trail of destruction to buildings and infrastructure. High winds can tear roofs off buildings and turn trees and cars into projectiles. The resulting damage compromises roads, electrical lines, cell towers, and buildings of all sizes. Storm surge follows a similar pattern. Strong currents can pick up large floating objects like boats and ram them into bridges and flooded buildings. Slow- moving hurricanes increase the chance of widespread flooding in the short term, as well as the risk of mold and mosquitoes a few weeks after the event. Finally, tropical storms often occur during summer months, placing occupants of under insulated buildings and buildings without operable windows at risk of heat-related illness if power is not quickly restored.

Building codes identify many types of healthcare facilities as critical infrastructure. As a result, modern facilities are designed to withstand structural damage from high winds and flood waters. They are also required to install sufficient on-site emergency power and water storage to maintain clinical operations for several days of utility outages.

Climate resilient healthcare organizations at risk of exposure to tropical storms can add to this baseline by planning for a future of more frequent and severe events and increased risk of extended power outages, boil water notices, and unsafe travel conditions. Planning efforts will include developing protocols supporting staff and their families during and after hurricanes, developing a spatial and clinical plan for accommodating surges of both patients and community members seeking a place of refuge, as well as the purchasing and supply storage considerations that will make it possible to pivot to emergency operations when an event occurs. The facility itself can also be upgraded to minimize energy and water use and protect key equipment from flood waters. Additionally, installing a supplemental onsite renewable power supply – such as a cogeneration plant and/or campus microgrid – will greatly reduce the risk of disruption to facility operations during utility outages.

For example, while infrastructural and operational emergency preparedness measures at University of Texas Medical Branch in Galveston, TX (UTMB) protected the majority of patients, staff, animal research subjects, and infrastructure from Hurricane Ike (2008), 90% of the medical campus facilities sustained some level of damage and almost all of the animal research documentation was destroyed. In total, the institution lost its blood bank, pharmacy, radiology department, and food service. While generators were tested weekly before the storm, several were destroyed by the storm, others were not functional because their switchgear flooded, and the natural gas-fired generator failed when its supply line was severed. Pre-staged trailer-mounted auxiliary chillers and generators were also flooded by the storm surge. Lessons learned included placing emergency exits above the 500 year flood line (so that staff can enter and exit the facility when the flood gates are closed), staging emergency auxiliary equipment in a sheltered location away from direct wind and storm surge impact, and maximizing flexible working conditions so that staff can support the facility's emergency response from the safety of their homes or evacuation site (Goodwin et al., 2010).

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3. Assessment and Remediation of Vulnerabilities in Infrastructure and Operations, continued

The following sub-elements describe specific ways in which a healthcare organization can enhance its facility infrastructure and operations' resilience to hurricanes

3.1 **Staff Support:** Healthcare organizations depend on dedicated clinicians, administrators, and facilities and operations staff to deliver care. Many staff are highly motivated to deliver care in response to an emergency. However, staff and their families are often impacted by the same climate change-related hazards as the facilities in which they work. Practical considerations like transportation, childcare, and concern for their family may prevent them from fully participating in the response effort. By integrating staff protections and accommodations into hurricane emergency planning, healthcare organizations can alleviate logistical difficulties to allow staff to get to work during and after hurricanes. Hurricanes are often forecasted several days in advance. As a result, emergency management plans can be deployed early enough for administration and staff to jointly decide which staff will remain at work through the duration of the event and who would benefit from staying at home with their families until roads become passable and power is restored. These measures also reduce mental strain caused by worrying about loved ones at home, allowing staff to focus on providing essential patient care.

3.2 **Clinical Considerations:** Hurricanes can cause a surge in healthcare demand due not only to acute injury during the event, but also to disruption in routine care and hazards that persist after the storm event. The majority of hurricane-related direct health outcomes in the U.S. can be traced to disruption in routine medical care for existing patients in the days and weeks post-disaster. These conditions can be prevented by ensuring that displaced patients are connected with nearby services until they return home (Toner et al., 2017). Storm surge (caused by strong winds pushing water to shore) is historically the leading cause of hurricane-related deaths in the U.S (US Department of Commerce, n.d.). Flooding can result in outbreaks of waterborne illness, and mold in its aftermath can trigger allergies and asthma. Power outages can increase the risk of extreme temperature exposure and put at risk those who depend on medications requiring refrigeration or electricity-dependent durable medical equipment (DME). Mental and behavioral health conditions can also be caused and exacerbated by the loss of loved ones, homes, and community infrastructure. Healthcare organizations can increase resiliency to hurricanes by integrating hurricane-specific clinical considerations into their emergency preparedness plans and adjusting normal procedures and standards of care ahead of forecasted events.

3.3 **Building and Campus – Design & Construction:** While building codes require structural redundancies that harden buildings against potential environmental hazards, facilities in the path of hurricanes are at risk of damage from high winds, intense precipitation, and flooding.

Hurricane-resilient healthcare facilities incorporate features such as energy efficiency and on-site power generation, water efficiency and emergency water supplies, and protective siting of critical building systems to minimize infrastructure damage from wind, flood waters, and storm surge.

3.4 **Building and Campus – Facility Operations:** Healthcare buildings are vulnerable to power outages because they rely on electricity, plumbing systems, and energy sources like natural gas to operate systems that are critical to patient care and occupant safety (such as lighting, air conditioning, medical and sterilization equipment, security systems, fire alarms, and electronic medical records) (FEMA ASPR, 2019). Most hospitals are sealed buildings, and loss of power during hurricanes can cause internal temperatures to rise or fall to dangerous levels (Patel et al., 2022). Many hospitals do not connect their facility systems to their backup power supply. Therefore, if electricity supply is disrupted during a hurricane, facility ventilation may function without access to heating or cooling systems, leading

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3. Assessment and Remediation of Vulnerabilities in Infrastructure and Operations, continued

to dysregulated internal temperatures (Balbus et al., 2016). Inpatients also require food service, access to clean water, and laundry and custodial services (FEMA ASPR, 2019). Operational resilience starts with design conversations about the building shape and structure, the location and type of windows, the building's overall insulation, its roof type and color, and the extent to which landscaping will be used to protect the building from exposure to hazards like flooding (Element 3.3). Healthcare organizations can enhance climate resilience in operational facilities by updating protocols for preventive maintenance and plans for cycling down systems during power outages to reflect the results of the organization's prospective risk assessment (Element 1).

3.5 **Supply Chain:** Many items in a healthcare organization's supply chain – both clinical and non-clinical – require refrigeration. Furthermore, hurricanes can also cause shortages of vital medical supplies and pharmaceuticals due to transportation disruptions and damaged production facilities. Healthcare organizations can enhance resilience by developing and implementing a plan for managing their refrigerated supply chain and on-site storage during power outages (Rublee et al., 2021). In addition, hurricane emergency planning should include additional assessment of supply chain vulnerabilities, with contingencies that can be implemented in the event of regional transportation or production disruptions.

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3.1 Staff Support

Healthcare organizations depend on dedicated clinicians, administrators, and facilities and operations staff to deliver care. Many staff are highly motivated to deliver care in response to an emergency. A study in Hawaii found that both physicians and nurses show particularly strong commitment to staffing major natural disasters like hurricanes compared with other emergencies, such as explosions or chemical events (83% compared with 52%-67% for other incidence types) (Lanzilotti et al., 2002). However, staff and their families are often impacted by the same climate change-related hazards as the facilities in which they work. Practical considerations like transportation, childcare, and concern for their family may prevent them from fully participating in the response effort. For example, a survey of over 6,000 healthcare workers in New York City found that 53% had childcare responsibilities, 63% of whom had children under the age of 13. 27% reported elder care responsibilities and 29% reported that their spouse also had work responsibilities during disasters (Qureshi, 2005). By integrating staff protections and accommodations into hurricane emergency planning, healthcare organizations can alleviate logistical difficulties to allow staff to get to work during and after hurricanes. Hurricanes are often forecasted several days in advance. As a result, emergency management plans can be deployed early enough for administration and staff to jointly decide which staff will remain at work through the duration of the event and who would benefit from staying at home with their family until roads become passable and power is restored. These measures also reduce mental strain caused by worrying about loved ones at home, allowing staff to focus on providing essential patient care. For example, 100 personnel from the U.S. Department of Veterans Affairs (VA) New York Harbor Healthcare System's (NYHHS) Manhattan campus slept at least one night at a VA facility during Superstorm Sandy so that they could continue providing care during the event (Wyte-Lake et al., 2018).

Climate Resilience Actions

Tools and resources relevant to these actions can be found at:
HURRICANES: Element 3.1: Staff Support

Planning

ACTION: Set staff expectations for their role during severe storms.

SUMMARY: Clearly define expectations with healthcare facility staff related to working during and after severe storms – particularly under circumstances that lead to power disruptions or outages, and those that may require staff to remain at work for extended periods. Share with staff a list of personal items that they should bring with them to an anticipated multi-day response effort, such as food, water, personal medication, hand sanitizer, extra clothes, and sleeping gear. Co-create policies and programs with staff establishing a flexible and supportive approach to staffing, accommodations, and transportation during and after severe storms. For example, it may be necessary to shorten staff shifts during emergency operations to give them the ability to rest mentally and physically.. Include daycare, shelter, and other accommodations for staff family members, as needed (Danna et al., 2010; Toner et al., 2017; WHO, 2020).

Climate Resilience Actions continued on next page

Climate Resilience Actions, continued

ACTION: Integrate regular emergency preparedness employee training into the healthcare organization's continuing education program.

SUMMARY: Implementing a regular emergency preparedness employee training program can increase awareness of climate change-related risks to the healthcare organization, as well as protocols and procedures designed to enhance resilience in the face of increasingly frequent and severe climate change-related events (Hilton, 2015; WHO, 2020). Include training on how key staff roles will be assigned during emergencies, and consider developing checklists for each department breaking down key tasks according to when they should occur – pre-event, during response, and post-event (HHS, 2014).

ACTION: Train clinical staff in alternative procedures for delivering care during disasters.

SUMMARY: Healthcare organizations can support staff in preparing for disaster response by offering training in alternative procedures for intake and triage if inpatients are transferred from other facilities without their medical records, as well as training in alternative procedures for delivering care in situations with limited access to electricity and water, such as manually counting IV pump drips, manually suctioning intubated patients, and manually taking blood pressure readings (HHS, 2014).

People and Operations

ACTION: Provide alternative transportation and housing for healthcare staff during severe storms.

SUMMARY: Consider establishing agreements with nearby transportation providers and temporary housing facilities (such as hotels) to support employees and their immediate families (including pets) in the event that transportation pathways and/or utilities are disrupted during a severe storm. This may also involve preparing for staff to stay at healthcare facilities before the storm begins to mitigate potential transportation interruptions (Morris et al., 2016; WHO, 2020).

ACTION: During transportation disruptions, coordinate across the healthcare system to redistribute staff to facilities they can access – even if they are not their "home" facility.

SUMMARY: It may be necessary immediately following events that damage infrastructure – such as hurricanes, severe inland storms, and floods – to temporarily redistribute the healthcare system's staff to facilities they can access (Morris et al., 2016). Establish a tracking system so that staff can report to supervisors who are physically located in different facilities (Wyte-Lake et al., 2018). Cross training staff so that they can fulfill multiple roles can benefit the overall healthcare system by ensuring that essential clinical services are offered by a mixture of permanent and temporary staff (Hilton et al., 2015).

ACTION: Ensure that staff who are supporting a hurricane response have access to clothing, a place to sleep, routine medications, and wellness services.

SUMMARY: Given the often-rapid evolution of hurricanes and their impacts on community infrastructure, staff may be required to stay at their place of work for more than 24 hours without access to basic necessities such as a change of clothes and daily medications. Healthcare organizations can increase the resilience of their clinical services by ensuring that staff have access to clothing, a place to sleep, routine medications, and wellness services while they support patients in the midst of a disaster (Evans, 2017; Hilton et al., 2015; Morris et al., 2016; Toner et al., 2017).

ACTION: Establish a culture that acknowledges the personal challenges staff are facing during a disaster.

SUMMARY: Acknowledging the personal challenges faced by staff during a climate change-related disaster can increase a healthcare facility's resilience by increasing the willingness of staff who are able to report to work. It also creates space for staff to request tangible assistance (such as a hotel room or childcare) that would make it possible for them to support the disaster response (Morris et al., 2016; Toner et al., 2017).

ACTION: Provide staff support post-disaster.

SUMMARY: Creating a post-disaster employee assistance program for staff and their families in the aftermath of a severe storm – including mental health services – can help them build the long-term physical, mental, and social resilience that will be needed to respond to the next disaster (Dana et al., 2010; WHO, 2020). Immediate

Climate Resilience Actions continued on next page

Climate Resilience Actions, continued

support for staff who have experienced a major loss (such as their home) can also increase their ability and willingness to return to work after the event (Morris et al., 2016).

ACTION: Provide staff with post-disaster safety information for their homes.

SUMMARY: After floods and hurricanes, healthcare organizations can share information with staff about how to inspect their homes for flood damage, how to remove water-logged and contaminated building materials, how to reduce the risk of mold growth, and funding opportunities to support demolition and rebuilding efforts (CDC, 2019).

Physical Infrastructure

ACTION: Establish alternative communications channels for contacting staff during utility outages.

SUMMARY: Staffing during and immediately following climate change-related disasters that cause utility outages can be complicated by disruptions to telecommunications infrastructure. Establishing alternative communications channels (such as multiple cell phone providers, satellite phones, walkie-talkies, and installing a generator-powered cell tower on the roof of the facility) can increase a healthcare organization's resilience to these events by making it possible to share important information with staff – such as facility closures and requests that staff report to the facility closest to their home (HHS, 2014; Morris et al., 2016; Wyte-Lake et al., 2018).

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3.2 Clinical Considerations

Hurricanes can cause an increase in healthcare demand due not only to acute injury during the event, but also to disruption in routine care and hazards that persist after the storm event. The majority of hurricane-related direct health outcomes in the U.S. can be traced to disruption in routine medical care for existing patients in the days and weeks post-disaster. These conditions can be prevented by ensuring that displaced patients are connected with nearby services until they return home (Toner et al., 2017). Following Hurricane Katrina in 2005, a mobile hospital deployed from North Carolina reduced the risk of patient surge in southern Mississippi by successfully treating 7,400 patients (Blackwell and Bosse, 2007). Storm surge (caused by strong winds pushing water to shore) is historically the leading cause of hurricane-related deaths in the U.S (US Department of Commerce, n.d.). Flooding can result in outbreaks of waterborne illness, and mold in its aftermath can trigger allergies and asthma. Power outages can increase the risk of extreme temperature exposure and put at risk those who depend on medications requiring refrigeration or electricity-dependent durable medical equipment (DME). Mental and behavioral health conditions can also be caused and exacerbated by the loss of loved ones, homes, and community infrastructure. For example, youth in Puerto Rico following Hurricane Maria reported high rates of post-traumatic stress disorder and depressive symptoms (Orengo-Aguayo et al., 2019). After Hurricane Harvey (2017), Blue Cross Blue Shield of Texas reported that the number of diagnoses for infectious and parasitic diseases doubled in counties impacted by the hurricane. Diagnosis of substance abuse, pneumonia, and COPD all increased 3%. Use of telemedicine to access care also doubled, although the total number of medical visits was 20% lower than expected immediately following the event (BCBS, 2018). Healthcare organizations can increase resiliency to hurricanes by integrating hurricane-specific clinical considerations into their emergency preparedness plans and adjusting normal procedures and standards of care ahead of forecasted events.

Climate Resilience Actions

Tools and resources relevant to these actions can be found at:
HURRICANES: Element 3.2: Clinical Considerations

Planning

ACTION: Integrate epidemiological and meteorological data into extreme heat event preparedness.

SUMMARY: Consider combining local epidemiological and meteorological data with downscaled climate models for your region to estimate the increase in patient volume (and corollary staff and medical supplies) that might be expected for different levels and durations of extreme heat events (Patel et al., 2022).

ACTION: Develop a continuity of care plan listing essential clinical services that will be provided at different tiers of utility disruption.

SUMMARY: Many healthcare facilities are designed to function at full or partial capacity under a variety of environmental stressors. Organizations can increase resilience to climate change-related events by creating and training staff to implement a continuity of care plan outlining essential clinical services that will be provided at different tiers of utility disruption (Toner et al., 2017).

Climate Resilience Actions continued on next page

Climate Resilience Actions, continued

ACTION: Enhance syndromic surveillance during severe storm and flooding events.

SUMMARY: Consider enhancing syndromic surveillance during storm and flooding events by submitting hazard-related illness data to the Electronic Surveillance System for the Early Notification of Community-Based Epidemics (ESSENCE) (Burkom et al., 2021). Work with local public health partners to interpret and act on real time hazard-related illness and all-cause morbidity and mortality data during and immediately following severe storms and floods.

ACTION: Enhance hurricane preparedness by adding hazard-related illness screening to the healthcare organization's electronic medical records system.

SUMMARY: Consider including in your organization's hurricane resilience and preparedness plan a protocol for activating hazard-related illness screening questions in the electronic medical records system when local authorities activate the emergency operations center to respond to an approaching hurricane (Hess et al., 2023). Sensitive patient groups that might be flagged for additional screening during and after hurricane events include unhoused individuals, children, adults over 65 years of age (especially those who live alone), coastal communities, low-income populations, and patients with chronic conditions. Early identification through electronic medical record (EMR) screening allows healthcare providers to flag sensitive patient groups for further evaluation and intervention, ultimately improving patient outcomes during hurricanes.

ACTION: Integrate mosquito-borne and water-borne infectious disease protocols into the healthcare organization's hurricane emergency plans.

SUMMARY: Consider including triage and syndromic surveillance protocols for mosquito-borne and water-borne infectious diseases in the healthcare organization's hurricane emergency plan to streamline appropriate clinical responses and public health reporting during and after tropical storm events (Hedges et al., 2018). Keep the protocol in place for several days or weeks after the hurricane passes, because incidence of both classes of disease is often associated with the after-effects of infrastructure damage, such as standing water, power outages, and boil water notices.

People and Operations

ACTION: Adjust normal procedures and standards of care ahead of forecasted hurricanes to expedite patient discharges when possible and to adjust the timing of routine treatment.

SUMMARY: Consider establishing protocols triggering an adjustment to the healthcare organization's clinical procedures (e.g., in pharmacy, drug treatment, dialysis, etc.) ahead of forecasted hurricanes to create contingency plans to extend the amount of time existing patients can go without routine treatment. When possible, expedite inpatient discharge to free up bed space ahead of expected patient surges during and immediately following the event (Scott, 2017; Toner et al., 2017).

ACTION: Develop a plan for patient surges and train staff in its implementation, including scenarios for accommodating cascading and simultaneous climate change-related disasters.

SUMMARY: Many climate change-related events occur simultaneously or in quick succession. For example, hurricanes often occur during heat waves. Wildfires, drought, flooding, and landslides often trigger or exacerbate each other. It is therefore increasingly important to develop a plan for patient surges and train staff in its implementation. Include procedures for bringing in temporary staff, adapting clinician services to fast-changing conditions, and altering the schedule for routine operating procedures to free up space and staff to provide emergency care (Toner et al., 2017).

ACTION: Co-locate critically ill and fragile patients on the same floor of the facility as the emergency command center to maximize staff communication and patient safety.

SUMMARY: Identify the safest floors of the healthcare facility during severe storms. Consider co-locating the most critically ill and fragile patients on those floors alongside the emergency command center to expedite communication between leadership and staff to maximize patient safety (HHS, 2014).

Climate Resilience Actions continued on next page

Climate Resilience Actions, continued

ACTION: If it is necessary to evacuate patients during a disaster, consider sending nurses, nursing assistants and leadership staff with them to ensure continuity of care.

SUMMARY: Hospitals that evacuated patients alongside care staff and their leadership team during Superstorm Sandy reported lower rates of anxiety about the evacuation among patients and their families (HHS, 2014).

Physical Infrastructure

ACTION: Deploy mobile health units to take medical care to high risk patients in the community during transportation disruptions.

SUMMARY: Consider including in the healthcare organization's list of emergency response assets mobile units that are used to deliver routine care to community members. Use the organization's map of high risk patients – such as substance use disorder, dialysis, diabetes, and heart disease – (Element 1) to prioritize the provision of medical care during transportation disruptions caused by a climate change-related event (Toner et al., 2017).

Impact of Hurricanes on Health Care Facilities

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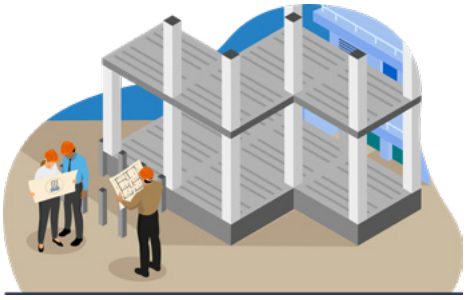
3.3 Building and Campus: Design & Construction



Although building codes require structural redundancies that harden buildings against potential environmental hazards, facilities in the path of hurricanes are at risk of damage from high winds, intense precipitation, and flooding. A 2022 study estimated that a category 2 hurricane would put over half of hospitals in 1/3 of urban areas along the Atlantic and Gulf Coasts of the U.S. at risk of flooding at current sea levels. By 2100, that risk was estimated to increase by 22% due to anticipated sea level rise (Tarabochia-Gast et al., 2022).

Hurricane-resilient healthcare facilities incorporate features such as energy efficiency and on-site power generation, water efficiency and emergency water supplies, and protective siting of critical building systems to minimize infrastructure damage from wind, flood waters, and storm surge. For example, in response to Hurricane Harvey, Lyndon B. Johnson Hospital in Houston, TX, reorganized interior spaces, creating a "quick care" flex area to process low acuity patients and setting up an annex to house 183 community members seeking shelter from the storm, which lasted for five days. Some of those sheltering in the hospital required ambulatory medical care or access to their regularly prescribed medications (Chambers et al., 2020).

Climate Resilience Actions

Tools and resources relevant to these actions can be found at:
HURRICANES: Element 3.3: Building and Campus – Design and Construction

Planning

ACTION: Use regional climate models to future-proof the efficiency and redundancy of building systems in the face of projected increases in the frequency and severity of climate change-related hazards.

SUMMARY: Building codes and engineering best practice guides use historical weather trends to set guidelines for the overall capacity of building systems, the maximum temperature at which they will function, and expectations for "average" temperature and rainfall. Climate models indicate that using historical trends to set the outer limits of building system functionality will likely fall short of operational needs within a few decades. It is therefore advisable for healthcare facilities (many of which are designed to function for 50 or more years) to maximize energy efficiency and identify opportunities for diversifying their energy supply (such as by installing renewable power microgrids for backup power) in order to extend the functional life of the building as long as possible in a rapidly changing climate (Casanueva et al., 2019).

People and Operations

ACTION: Work with consultants who are familiar with climate resilient design and construction techniques.

SUMMARY: Working with architects, engineers, owner's representatives, and general contractors who are knowledgeable about the different design strategies, building technologies, and materials required to build and operate a climate resilient healthcare facility is often

Climate Resilience Actions continued on next page

Climate Resilience Actions, continued

key to integrating climate resilience planning into a new building, renovation project, or facility upgrade (Darko et al., 2017).

Physical Infrastructure

Landscaping and Roof

ACTION: Provide and maintain safe, shaded pathways between the property line or patient drop-off point and the facility entrance for multiple modes of transportation.

SUMMARY: Providing shaded pathways linking the facility's main entrance with transit stops, parking, and other access points can increase the safety and effectiveness of multi-modal evacuation plans when they are deployed during a climate change-related event (Basu et al., 2022).

ACTION: Maximize green space on the ground level and facility roofs to reduce exposure to heat and flooding.

SUMMARY: Installing native, drought-resistant landscaping and nature-based solutions like low impact development on both the ground level and facility roofs can reduce utility costs (both energy and water) and reduce exposure to extreme heat. Low impact development and green roofs further reduce flood risk by filtering stormwater and slowing its movement across the property (Chu et al. Figure 12.7, 2023).

Energy Efficiency and Renewable Energy

ACTION: Establish a net zero requirement for all new buildings and major renovations in the healthcare system.

SUMMARY: Net zero facilities are designed with enough energy efficiency measures (e.g., enhanced building and wall insulation, efficient building and mechanical equipment, and efficient lighting systems) to reduce their energy demand to a level at which they can generate sufficient electricity using on-site renewable power (e.g., solar, wind, geothermal). These facilities can continue to provide clinical care during disasters that disrupt regional power grids. For more information about net-zero buildings, see: A Common Definition for Zero Energy Buildings | Department of Energy.

ACTION: Install energy efficient building equipment to extend the length of time during which the facility can function on back-up power systems.

SUMMARY: Installing energy efficient building equipment (such as air conditioning, heating, ventilation, and lighting systems) can reduce demand for air conditioning and heating and extend the length of time during which the facility can function on back-up power systems (Carvallo, et al., 2022.

ACTION: Increase resilience to power outages by installing cogeneration facilities on site or in the medical district.

SUMMARY: Investing in an on-site or district-wide cogeneration plant connected to secure power sources, such as geothermal, and storage capacity can reduce a healthcare facility's reliance on external power sources needed to maintain continuity of care (Isa et al., 2018).

Water Efficiency and Flood Resilience

ACTION: Maximize water efficiency to reduce demand during low water pressure and boil water notice events.

SUMMARY: Water is critical to the functioning of healthcare facilities– both clinical and building systems. To maximize the availability of potable water for clinical uses, consider minimizing once-through use in process equipment – such as the heating, ventilation, and air conditioning (HVAC) system, sterilizers, and medical equipment. Further, consider installing low flow toilets, urinals, hand wash stations, and showers – except where volume is needed for occupational uses (such as water filling stations and decontamination showers) (van der Heijden, 2022; WHO, 2015).

ACTION: Separate potable and process water systems from each other and source an emergency water supply to maintain water pressure during water outages.

SUMMARY: Water pressure can drop in a community during extreme weather events (e.g., extreme heat, extreme cold, and drought) or as a result of infrastructure failures caused by hazards like hurricanes and tornadoes. Healthcare facilities should be designed to operate using on-site water supplies for at least 72 hours. Facilities located in high-risk areas can increase resilience by

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Climate Resilience Actions, continued

identifying supplementary water sources (such as connections to allow temporary water supply from trucks or other sources, permanent storage tanks/cisterns, and wells) that can be used to maintain water pressure during low pressure events. Facilities with the ability to separate process water systems from potable water systems are particularly resilient to water outages (HERC, 2015; van der Heijden, 2022; WHO, 2015).

ACTION: Protect the permanent and emergency water supply from extreme weather and contamination from flood waters.

SUMMARY: Weatherize water supply pipe, cisterns, and tanks to prevent breakages in extreme cold weather. Place emergency water storage (such as tanks and cisterns) outside of areas at risk of flooding or landslides. Install float valves and overflow outlets that drain away from the facility to avoid flooding interior spaces after a cistern or tank fills up. Install one or more supplementary water pumps (depending on need) and connect them to the emergency power supply to keep water pressure at safe levels when the power goes out (van der Heijden, 2022; WHO, 2015).

ACTION: Install backflow prevention valves to prevent sanitary sewage from backing up into the hospital during flood events.

SUMMARY: Healthcare facilities located in communities with combined sanitary and storm sewers may experience sewage backup during extreme flood events. Facilities can enhance resilience by installing backflow prevention valves and capping drains on lower floors during flooding events (van der Heijden, 2022; WHO, 2015).

ACTION: Design new buildings and reinforce existing structures to withstand future climate change-related exposures as described in the healthcare organization's prospective risk assessment (Element 1).

SUMMARY: Many building codes rely on historical data to set structural requirements for withstanding climate change-related hazards like wind, flooding, fire, heat, and landslides. Healthcare organizations can reduce the risk of a major disaster causing sufficient physical damage to shut down operations by designing and renovating facilities to withstand future climate change-related exposures as described in their prospective risk assessment (Element 1) (HHS, 2014).

ACTION: Install protective barriers and elevated walkways/driveways in areas at risk of flooding.

SUMMARY: Flood gates, flood walls, and other barriers equipped with crossover stairs can support safe passage across areas on a medical campus that are projected to experience repeated flooding (HHS, 2014).

Thermal Comfort and Indoor Air Quality

ACTION: Install operable windows with screens in non-clinical spaces to increase the healthcare facility's resilience during power outages.

SUMMARY: Installing operable windows with screens can extend the period of time a healthcare facility can function during a power outage by reducing reliance on the air conditioning system for cooling and ventilation (Sun et al., 2020).

ACTION: Install high efficiency air filtration systems to reduce the concentration of pollutants in indoor air.

SUMMARY: Installing highly efficient air filtration systems (e.g., MERV 13) and increasing the volume of outdoor air introduced to the building can reduce the concentration of a range of airborne contaminants, including airborne pathogens; particulate matter; cleaning and disinfection chemicals; and toxins emitted from furniture, architectural finishes, and composite wood products like plywood (Mousavi et al., 2020).

Resilient Critical Operating Systems

ACTION: Place the healthcare organization's critical infrastructure above the level of projected flood risk.

SUMMARY: Placing equipment crucial to research, education, and patient care (such as labs, medical equipment, and IT equipment) and building systems (such as emergency generators, pumps, and electrical switches) above the level of projected flood risk can reduce the likelihood of disruptions to patient care and research resulting from facility flooding (HHS, 2014; Scott, 2017).

Climate Resilience Actions continued on next page

Climate Resilience Actions, continued

ACTION: Place electronic medical record servers and equipment in climate-controlled spaces and above the flood line.

SUMMARY: To ensure that medical information systems remain functional during power outages and flooding events, place them in storage spaces that are elevated above the risk of flood waters, climate-controlled with a dedicated energy source, and/or off-campus (such as a duplicate paper record storage site) (Commerce, 2010; HHS, 2014).

ACTION: Place redundant IT systems off-site to increase the resilience of electronic medical records.

SUMMARY: Placing redundant IT systems off-site can reduce the risk of the electronic medical records system going offline during flood events (Danna et al., 2010; Toner et al., 2017).

ACTION: Install redundant communication systems for use during power and communications outages.

SUMMARY: Extreme weather events can disrupt electricity supply, cell towers, radio transformers and other community communications networks. Healthcare organizations can reduce the risk of disruption in communications to other facilities in their network, regional healthcare organizations, and local emergency management agencies by installing and maintaining redundant communication systems, such as analog phones, fax machines, handheld two-way radios, ham radios, and solar-powered devices (Hedges et al., 2018).

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3.4 Building and Campus: Facility Operations

Healthcare buildings are vulnerable to power outages because they rely on electricity, plumbing systems, and energy sources like natural gas to operate systems that are critical to patient care and occupant safety (such as lighting, air conditioning, medical and sterilization equipment, security systems, fire alarms, and electronic medical records) (FEMA ASPR, 2019). Most hospitals are sealed buildings, and loss of power during hurricanes can cause internal temperatures to rise or fall to dangerous levels (Patel et al., 2022). Many hospitals do not connect their facility systems to their backup power supply. Therefore, if electricity supply is disrupted during a hurricane, facility ventilation may function without access to heating or cooling systems, leading to dysregulated internal temperatures (Balbus et al., 2016). Inpatients also require food service, access to clean water, and laundry and custodial services (FEMA ASPR, 2019). Operational resilience starts with design conversations about the building shape and structure, the location and type of windows, the building's overall insulation, its roof type and color, and the extent to which landscaping will be used to protect the building from exposure to hazards like flooding (Element 3.3). Healthcare organizations can enhance climate resilience in operational facilities by updating protocols for preventive maintenance and plans for cycling down systems during power outages to reflect the results of the organization's prospective risk assessment (Element 1).

For example, Lee Health System in Florida prepared for Hurricane Ian (2022) by stockpiling supplies and generator fuel ten days prior to the storm. They also halted all construction three days prior to the storm, performed a walkthrough of all facilities to minimize loose debris that could be picked up by hurricane winds and cause damage, and staged repair materials and equipment in locations that were at greatest risk of physical damage. Even with all of their precautions, the health system faced an extended period of low and no water pressure across many of their facilities. They responded by activating their fire watch plan (due to low water pressure in their sprinkler system), reducing the number of toilets in use, rationing drinking water to critical functions, and working with local offices of emergency management to access backup water tankers (ASPR TRACIE, 2023).

Climate Resilience Actions

Tools and resources relevant to these actions can be found at:
HURRICANES: Element 3.4: Building and Campus – Facility Operations

Planning

ACTION: Integrate pre-event resilience measures into healthcare facility operations preventive maintenance and emergency management plans.

SUMMARY: Pre-event resilience measures in healthcare facilities include maintaining building systems to maximize energy efficiency and enhanced ventilation, diversifying the energy supply (such as installing renewable power and battery storage for backup power), increasing insulation and solar reflection for the facility walls and roof, installing shading devices to minimize heat exposure inside the building, and performing routine maintenance to seal cracks and fix plumbing leaks (Casanueva et al., 2019).

Climate Resilience Actions continued on next page

Climate Resilience Actions, continued

ACTION: Categorize electricity loads by their contribution to critical operations.

SUMMARY: Healthcare facilities can increase resilience to power outages by creating a load-shedding protocol that powers down building systems based on their level of importance to clinical care. Consider cross-referencing the protocol with stages of evacuation preparation, so that patient transfers to partner facilities take place before conditions (such as extreme temperatures, exposure to flood waters, etc.) reach dangerous levels (FEMA ASPR, 2019).

ACTION: Perform a baseline analysis of water usage and categorize usage types into tiers of critical need.

SUMMARY: Water is a critical component of clinical care, including sanitizing medical equipment. Performing a baseline analysis of the healthcare facility's water usage and categorizing usage types into tiers of critical need can help facility managers direct potable water supply to the most important clinical needs during low water pressure and boil water notices while also reducing overall facility water usage (WHO, 2015; van der Heijden, 2022).

ACTION: For hurricanes that could result in widespread damage to utilities and community infrastructure, include security considerations in the healthcare facility's emergency preparedness plan.

SUMMARY: Extreme weather events that cause widespread damage to utilities and community infrastructure can result in a temporary need for increased security at a healthcare facility, particularly if it experiences a patient surge and/or acts as a place of respite for community members (Danna et al., 2010).

People and Operations

ACTION: Implement a preventive maintenance program to ensure that energy efficient building systems function as designed.

SUMMARY: All building systems require regular maintenance. Preventive maintenance, an approach to regularly inspecting and tuning equipment, is particularly important for facilities that are designed to continue operations during utility outages. These programs ensure that the energy and water demand remain at levels that can be met by on-site sources, such as renewable power and recycled process water (Kolokotsa et al., 2012). and recycled process water (Kolokotsa et al., 2012).

ACTION: Conduct regular stress tests of the healthcare facility's ability to continue providing clinical care during extreme weather events.

SUMMARY: Consider performing regular stress tests of the healthcare facility's ability to continue providing clinical care during extreme weather events. Incorporate scenarios that involve power outages, low water pressure, a surge of patients experiencing hazard-related illness, a surge of all-cause complaints, and a surge of community members seeking to use the facility as a resilience hub and safe place to charge electrical devices (including medical equipment). Stress tests can help identify critical systems (such as vacuum suction systems and electricity-dependent medication delivery systems) whose failure would result in cascading effects across the facility and impact delivery of critical care (Ebi et al., 2018).

ACTION: Conduct regular tests of emergency generators, water supplies, and transportation plans to ensure that they are ready to deploy in the event of an emergency.

SUMMARY: It can be difficult to source fuel, water trucks, and emergency transportation contractors in the immediate run up to a hurricane. Healthcare organizations can check the status of their resilience to the first 72 hours of anticipated hurricanes by performing regular tests and maintenance on emergency generators and on-site sources of emergency water. It can also be helpful to perform regular drills with outside contractors who will be responsible for supplying more fuel, trucked in water, emergency transportation for staff and patients, and other activities included in the facility's emergency operations plan (HHS, 2014).

Physical Infrastructure

ACTION: Conduct regular walk-throughs of the healthcare facility to confirm compliance with fire safety and evacuation signage requirements

SUMMARY: Facility evacuation can be impeded if exits are obstructed, signage is missing or confusing, or life safety equipment like sprinklers and fire extinguishers

Climate Resilience Actions continued on next page

Climate Resilience Actions, continued

is missing or broken. Conducting regular walk-throughs of the healthcare facility to confirm that these essential emergency preparedness components are in place and in working order could be seen as a first level of resilience to any climate change-related hazard that might damage the building structure or result in an eventual evacuation (HHS, 2014).

ACTION: Generate renewable energy on the healthcare campus.

SUMMARY: Producing electricity on-site using renewable energy sources such as solar and geothermal coupled with storage capacity (e.g., batteries) can reduce reliance on external sources for electricity needed to maintain continuity of care (Lazo et al., 2023).

ACTION: Prior to an anticipated flooding and/or wind event, walk through the facility to identify locations that might require repair during and immediately following the event and stage the necessary materials and equipment (including pumps) nearby.

SUMMARY: Certain locations in and around the healthcare facility are more vulnerable to damage from a flooding and/or wind event, such as the roof, windows, and lower floors. Healthcare organizations can reduce the risk of disruption to clinical operations by identifying likely repair needs prior to the event and staging the relevant construction materials and equipment within easy reach to minimize the impact of minor leaks, broken windows, and other building damage on regular facility operations (ASPR TRACIE, 2023).

Impact of Hurricanes on Health Care Facilities

CR4HC

3.5 Supply Chain

Many items in a healthcare organization's supply chain – both clinical and non-clinical – require refrigeration. Hurricanes can cause shortages of vital medical supplies and pharmaceuticals due to storage and transportation disruptions and damaged production facilities. Healthcare organizations can enhance resilience by developing and implementing a plan for managing their refrigerated supply chain and on-site storage during power outages (Rublee et al., 2021). For example, an alternative care site in Louisiana stores a 14-day Emergency Inventory Package in a warehouse on-site to ensure that the facility has enough inventory to serve 240 patients over a two week supply chain disruption (Maslanka and Hurwitz, 2022). In addition, hurricane emergency planning should include an additional assessment of supply chain vulnerabilities, with contingencies that can be implemented in the event of regional transportation or production disruptions. For example, in addition to stockpiling supplies for patients and staff in the run up to Hurricane Maria (2017), Ponce Health Sciences University also stockpiled several days of food and water for animals in the institution's vivarium. In the days following the event, they transferred 3,500 tumor tissue samples to the H. Lee Moffitt Cancer Center in Tampa, FL to protect them from intermittent power outages (Hedges et al., 2018).

Climate Resilience Actions

Tools and resources relevant to these actions can be found at:
HURRICANES: Element 3.5: Supply Chain

Planning

ACTION: Integrate regional climate change projections into the healthcare organization's supply chain emergency planning process.

SUMMARY: Identifying potential vulnerabilities within a healthcare organization's supply chain related to the full range of regional projected climate change-related hazards can inform contingency planning and emergency preparedness planning, including establishing redundancy among providers for critical supplies (Lakatos et al., 2023; Sherman et al., 2023).

ACTION: Integrate medical supply storage into resilience planning.

SUMMARY: Consider how your organization's prospective risk assessment of hurricanes (Element 1) might lead to supply chain disruptions and/or changing needs. Maintain an adequate supply of medical supplies, particularly for products that are most vulnerable to weather-related disruptions in transportation routes (Hedges et al., 2018). Consider separating emergency supplies into two categories: high volume medical supplies (such as IV bags, sharps, and oxygen) and equipment/supplies that would only be needed during a disaster. Establish a timeline for activating the supply chain plan ahead of the anticipated climate change-related event. Include in the timeline when a comprehensive check of both types of inventory should take place and when normal deliveries should be suspended (for example, 120 hours and 12 hours ahead of an anticipated hurricane, respectively) (Maslanka and Hurwitz, 2022).

Climate Resilience Actions continued on next page

Climate Resilience Actions, continued

People and Operations

ACTION: Require suppliers of essential goods and services to provide a continuity of operations plan for hurricanes.

SUMMARY: Healthcare organizations are dependent on a large network of vendors to supply goods and services that are essential to facility operations and continuity of care. Requiring suppliers of essential goods and services to provide a continuity of operations plan is an important first step in building the healthcare organization's resilience to hurricanes and other disasters that disrupt transportation infrastructure (Toner et al., 2017).

ACTION: Stockpile potable water.

SUMMARY: Maintaining a stockpile of potable water either inside the healthcare organization's storage facilities or through a contract with external vendors can bridge the gap both for medical procedures and community services (i.e., sharing bottled water with community members) during water shortages (Hedges et al., 2018).

Physical Infrastructure

ACTION: Boost the resilience of refrigerated storage areas.

SUMMARY: Consider increasing wall insulation and access to auxiliary power in refrigerated storage areas to extend the shelf life of temperature-sensitive products like pharmaceuticals and food supplies during brownouts and blackouts (Lazo et al., 2023).

ACTION: Store essential medical supplies, food, and fuel lasting 5-7 days on or near the healthcare campus to facilitate rapid deployment ahead of hurricanes.

SUMMARY: As the severity of hurricanes and duration of related disruptions increase due to the effects of climate change, it has become increasingly important to stockpile medical supplies, food, and fuel on or close to a healthcare facility campus in case utilities and transportation infrastructure are disrupted for multiple days (Danna et al., 2010).